CONVEYOR SYSTEMS IN UNDERGROUND IRON-ORE MINES, LAKE SUPERIOR DISTRICT

BY EUGENE O. BINYON

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by

Eugene O. Binyon[1/]

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1/ Mining engineer, Mining Division, Bureau of Mines.

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INTRODUCTION AND SUMMARY

Belt and shaker conveyors, used singly or as combined units, have for many years been an integral part of many coal-mine haulage systems. The belt conveyor has also been used extensively as a main haulage unit in open-pit iron-ore mines of the Lake Superior district, particularly on the Mesabi Range. Few underground metal mines, however, either in the ferrous or non-ferrous branches of the mining industry, use the conveyors exclusively or even extensively for underground haulage. At present, only five iron-ore mines in the entire Lake Superior district have belt- or shaker-conveyor installations of any significant size. Of these mines, three are in the Crystal Falls-Iron River district of Michigan on the Menominee Range, one is on the Marquette Range near Ishpeming, Mich., and one is on the Mesabi Range near Keewatin, Minn.

Results of the studies of tackless haulage in the Lake Superior district will not permit the establishment of any formula to prove or disprove the advantages of belt or shaker systems at all underground mines. The studies do show that trackless haulage can be used to advantage where the proper conditions exist. Advantages are particularly apparent when development can be planned sufficiently in advance of exploitation to permit installation of belts or shakers as part of the development program and where the systems are extended to include haulage in stopes as well as main entries.

SCOPE OF REPORT

During the winter of 1947-48, the Bureau undertook a study of all of the underground ore conveying systems known to be in operation in the Lake

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Superior district for the purpose of making available to the entire mining industry the technologic data developed in the area. Because conditions that led to the installation of the belt and shaker conveying systems were often a function of the character of the deposit or the method of mining, a brief description of those conditions is included in this report.

After a preliminary investigation into the extent to which trackless conveyors were employed in the district, it was found that a detailed study at five sites would result in fair appraisal of that method of haulage in the underground iron-ore mines.

Each of the five significant installations is described separately in this report. In one instance, however, company policy does not permit identification of the mine wherein the conveying is done. In that instance the operation is designated as mine "A".

Unless otherwise specified, all tonnage figures quoted herein are gross.

ACKNOWLEDGMENTS

The cooperation of officials of all of the companies operating underground mines in the Lake Superior district permitted successful completion of preliminary studies of mining practices and conveying systems.

Special acknowledgment is made to R. D. Satterley, general superintendent, and to operating staffs of the Sherwood and Morris mines of the Inland Steel Co. The assistance given by W. D. Whitman, assistant superintendent, and Douglas Tippett, mine captain at the Morris mine, and P. D. Pearson, superintendent, R. O. Marsten, engineer, and W. Johnson, mine captain, at the Sherwood mine, is acknowledged.

The assistance and suggestions offered by the management of Pickands Mather & Co. also is gratefully acknowledged. The descriptions of operations at the James and Bennett mines were reviewed under the direction of Kenneth Duncan, assistant manager, Pickands Mather & Co. H. J. Richards, general superintendent, and A. L. Johnson, underground superintendent at Caspian, Mich., and H. A. Niels, mine captain at the James mine, assisted the author in compiling the study. A. E. Schneider, superintendent, and J. E. Martinson, engineer, at the Bennett mine furnished much of the information required in the description of operations at the Bennett mine.

Acknowledgment is also made of the assistance and cooperation offered by the supervisory personnel of the Republic Steel Corp. F. H. Cash, district manager and E. W. R. Butcher, chief mining engineer of the company's district headquarters at Duluth, Minn., together with other supervisory personnel, assisted the author in reviewing the results of this study.

F. J. Carlson, mine inspector of Iron County, Mich., and M. L. Robertson of the Goodman Manufacturing Co., also supplied information that was helpful in the preparation of the report.

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Preliminary studies of haulage practices at underground mines in the district were made by G. A. Apell, mining engineer, Bureau of Mines. All of the detailed studies were made by the author under the direction of Paul Zinner, chief, Minneapolis Branch, Mining Division, Bureau of Mines.

SHERWOOD MINE

The Sherwood mine is in the Village of Mineral Hills, township of Iron County, Mich., 2.2 miles north of Iron River in sec. 23, T. 43 N., R. 35 W. The mine is operated by the Inland Steel Co. of Chicago, Ill.

The Sherwood was the first of the underground iron-ore mines on the Menominee Range to use belt conveyors for main-line haulage and at present has the second largest underground installation of belt and shaker conveyors in the Lake Superior district.

In 1945, after weighing the advantages and disadvantages of belt conveyor against trolley locomotive haulage, the management decided to install belt conveyors for main haulage on the 1,200-foot level.

Factors including the tonnage to be handled by the belts, the relative life of belt conveyors compared to electric-trolley locomotive and cars, the initial cost of equipment, operation and maintenance costs, as well as the difference in the amount of development work required for stoping operations using conveyor or locomotive haulage were all considered in reaching the decision to install belt-conveyor haulage.

Several of these factors, particularly the life of the belt and the operating and the maintenance cost, had to be estimated. Few or no data were available on how belt conveyors would stand up under an abrasive and heavy ore. Also, there was an absence of any specific information on the cost of operation and maintenance, as only one other mine in the Lake Superior district used belt conveyors for underground haulage under conditions comparable to those at the Sherwood. However, final calculations indicated that a reduction in haulage cost could be realized by using belt conveyors; and, in 1945, three conveyor units, having a total length of 2,100 feet, were ordered 2/ Installation was started in July 1946, and by October 10, 1946, two units were in operation. Later, 300 feet of the third conveyor unit was installed, and in February 1948 installation of the entire unit was completed.

In order to establish some criteria upon which to base comparisons between operations at the Sherwood and other mines where the use of belt or shaker conveyors may be contemplated, a brief description of the ore deposit, the lay-out of mine working, and the mining method, as well as the hoisting facilities and those factors already mentioned, is summarized in the following paragraphs.

2/ Pearson, Phillip D., Underground Iron-Ore Haulage by Belt Conveyor: Min. Cong. Jour., May 1947.

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Description of the Deposit

The ore occurs in a highly folded series of beds that form the south flank of a large synclinal structure. The axis of the structure strikes east and west and has a slight pitch to the west. West of the main north-south crosscut, shown on figure 1, the strike of the deposit is almost due east and west; east of the main crosscut the strike is N. 70° E. Near the extreme eastern end, the strike of the deposit is almost north.

Dip of the ore-bearing beds is steep and generally to the north.

The hanging or north wall, which is locally termed iron formation, is a hard, slatey, cherty rock containing a fairly high percentage of iron. Both ore and hanging-wall rock stand exceptionally well, in some instances having stood for long periods over openings up to 80 by 250 feet in area.

Black carbonaceous and pyritiferous slate containing some iron oxide minerals forms the footwall. It is weak and sloughs readily, and even small openings in it require timbering. Where possible, a shell of ore is usually left on this wall in stopes to prevent sloughing.

The deposit ranges in width from 50 to 250 feet and averages 200 feet. It has been mined for approximately 1,300 feet along the strike. The exact depth of the deposit is undetermined.

The ore is a dark-red and brown hematite and limonite with some quartz and kaolin and minor amounts of other minerals. It is of medium hardness, and although it is highly fractured by folding it has little tendency to cave freely. The folded and highly fractured character of the ore generally causes it to break fairly fine. There is some coarse breakage where patches or ribs of hard ore are encountered; however, relatively, few of these occur and the amount of secondary blasting required is not great.

An average analysis of the ore follows:

Analysis, percent - natural				
Fe	S	P	SiO_2	Moisture
51.75	0.15	0.5	6.0	8-9.5

Production

Ultimately, the production rate is expected to reach 500,000 tons per year, or approximately 1,800 tons per day. At present, production is maintained at about 1,500 tons per day.

Ninety to ninety-five men are employed for the two shifts worked per day; 55 to 60 of these are employed underground. The crews alternate shifts each week, a 6-day week being worked by the day shift and a 5-night week by the night shift.

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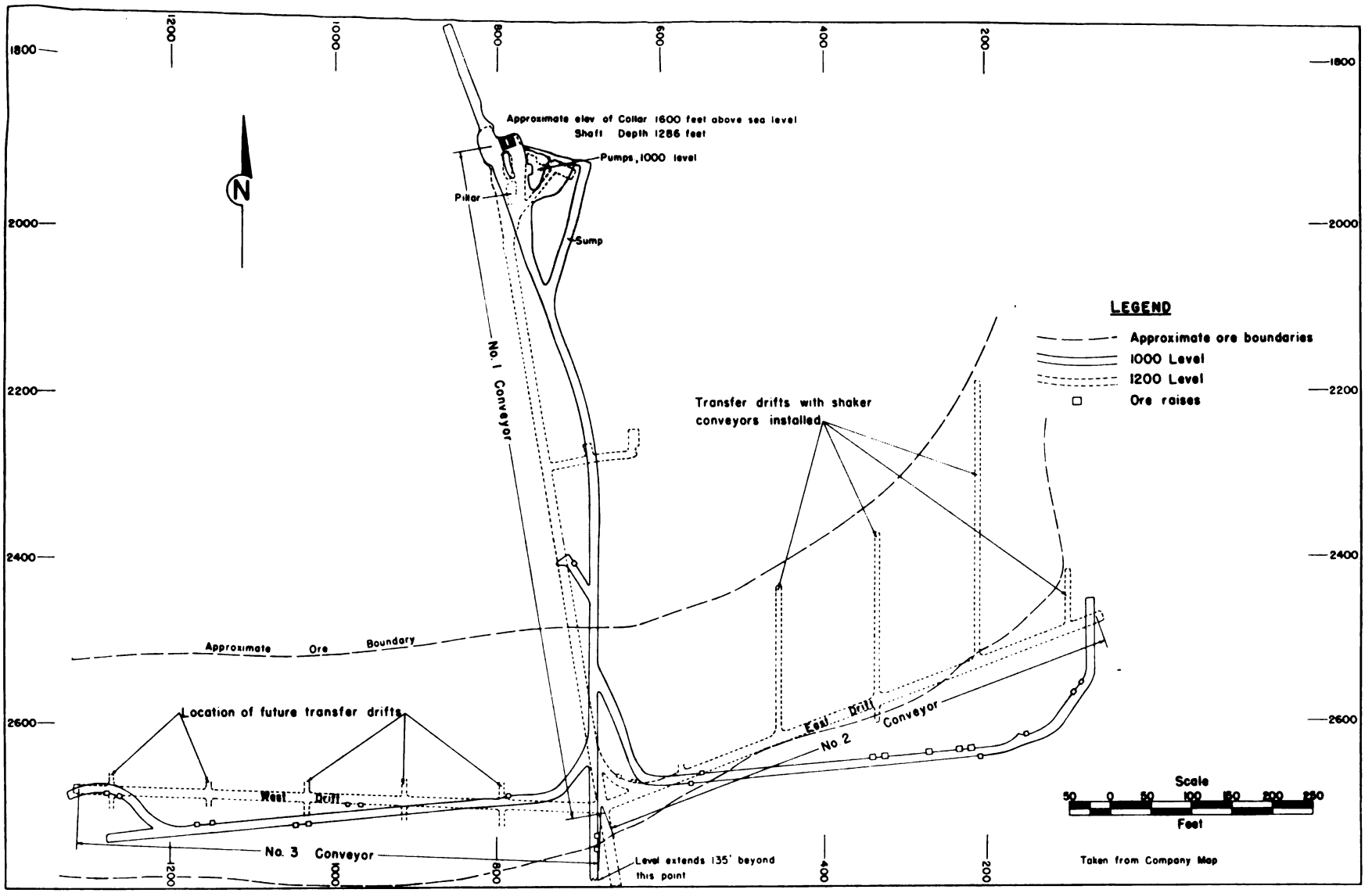

Figure 1. - Plan of the 1000 and 1200 levels of the Sherwood mine, Iron County, Mich.

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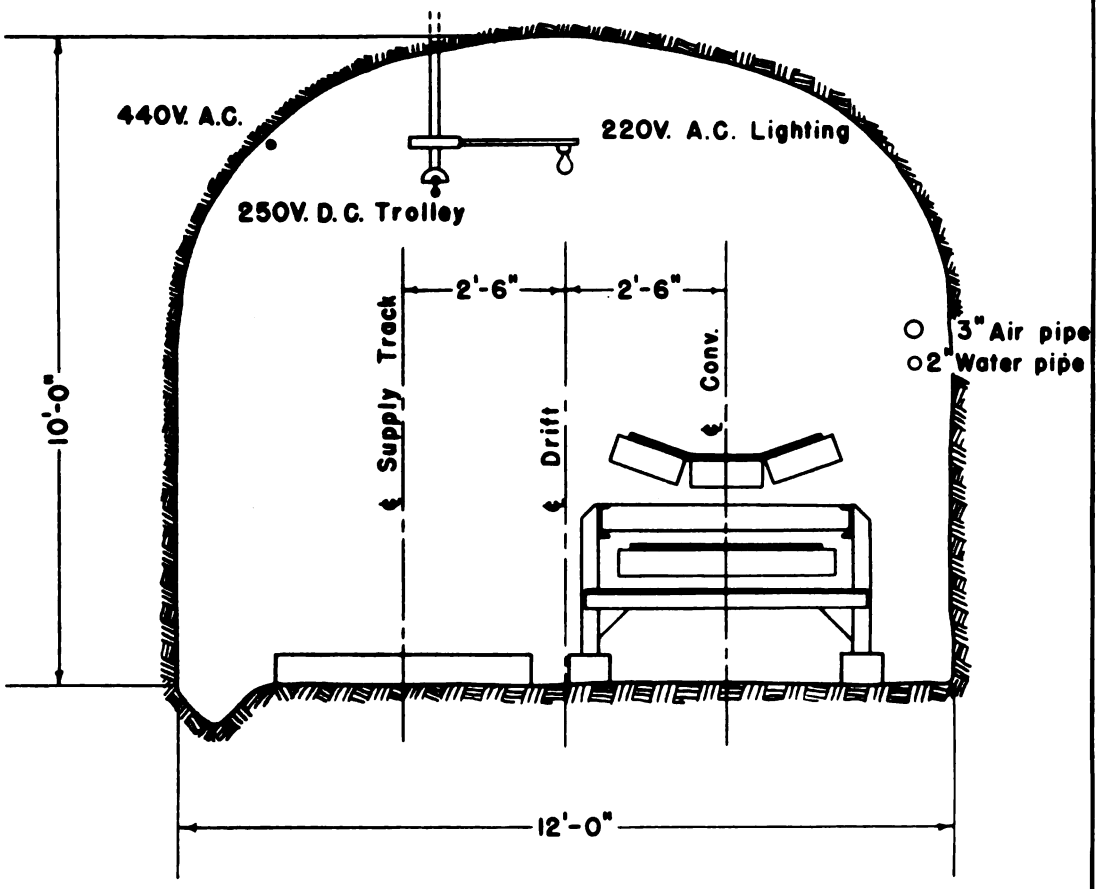

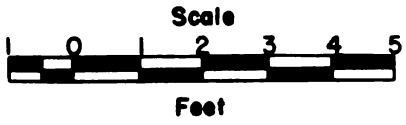

Taken From Company Drawing

Figure 2. - Typical section of 1200 level, Sherwood mine, Iron County, Mich.

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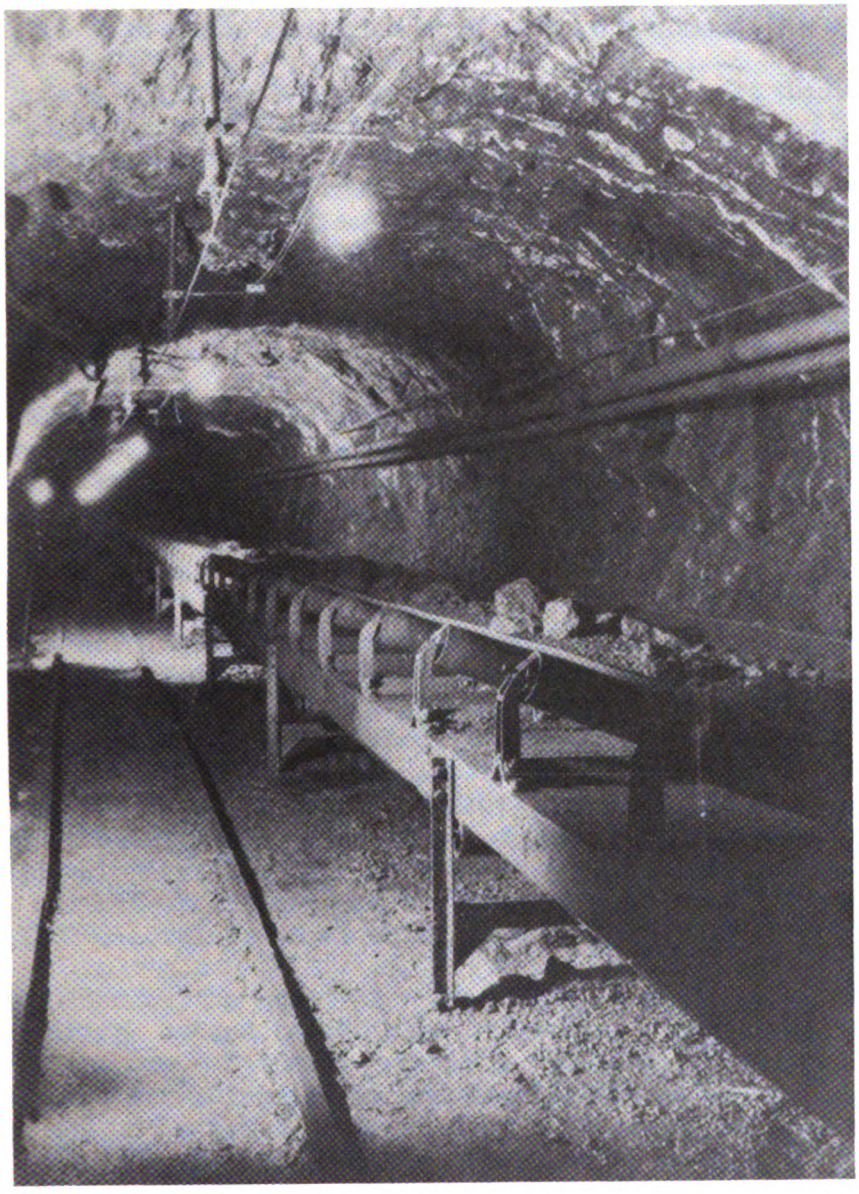

Figure 3. - View of 1,200 level east drift of the Sherwood mine, looking east. (Courtesy of Ferris Studio, Iron River, Mich.)

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Hoisting

Hoisting is done through a vertical 14-foot 10-inch by 10-foot (inside dimensions), 4-compartment shaft 1,286 feet in depth. The shaft, with steel sets and timber lagging throughout, is divided into 2 skip compartments, 1 cage compartment, a manway, and a slot for a counterweight for the cage. Steel skips having a capacity of 6 tons (100 cubic feet) are 3 feet 6 inches by 3 feet 8 inches by 8 feet 2 inches inside measurements and weigh about 5,500 pounds. The cage, also constructed of steel, accommodates 25 to 32 men.

The skip hoist, built in 1941, is a double, cylindrical, drum type, the drums having a diameter of 8 feet with a face width of 5 feet. It is driven by a 600-horsepower induction motor operating on 3-phase, 60-cycle power at 2,200 volts and 150 amperes. The motor speed at full load is 440 r.p.m. A single-drum hoist with a drum diameter of 9 feet and 8-1/2-foot face is used for the cage. This is driven by a 350-horsepower induction motor operating on 3-phase, 60-cycle power at 2,200 volts and 90 amperes. Motor speed is 442 r.p.m. at full load. Both hoists are equipped with controls to prevent overwinding.

Hoisting cables for both the cage and the skips are 1-1/4-inch, 6 by 19 regular lay, nonspin, improved plow steel. Cables are changed, end for end, about once a year, and are also interchanged between the cage and the skip hoist at regular intervals for minimum wear.

Mining Methods

The mine has been developed from four main levels driven from the shaft at depths of 400, 800, 1,000, and 1,200 feet below the collar. The two deepest levels, the main working levels at present, are shown on figure 1. These were extended to cut through the ore body to the south or footwall of the deposit. Drifts were driven along the strike in an east-west direction to the working limits of the mine, or about 700 feet in each direction. An effort was made to keep the drifts as close to the footwall as possible in order to simplify stope development and also to make it possible to draw all ore from the stope with one set-up of scrapers or shaker conveyors. A typical cross-section of the 1,200-level is shown on figures 2 and 3.

All ore is mined by the sublevel open-stoping method. In starting a stope, transfer drifts spaced on 120-foot horizontal centers are driven north to the limits of the ore. Formerly, on the 1,000 level, where the transfer drift was to be used for scraping, it was usually driven about 8 feet wide and 8 feet high and was started at a vertical distance of 22 feet above the main haulage level. On the 1,200 level, where shaker conveyors are now installed, the transfer drift is started only 4 to 5 feet above the level, and the size is reduced to about 6 by 7 feet. Some modification in the vertical spacing of the sublevels as well as spacing of the chutes in the transfer drift have been made in the stopes where shakers are now installed. Fewer chutes are required, and the sublevel interval is 35 feet instead of the 25- to 30-foot spacing formerly used. The main differences in the development of the stopes using shaker and scraper haulage is shown on

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figures 4 and 5. Usually in the stopes off the 1,200 level the manways near the footwall and ore raises are spaced about 15 feet apart; the manways are carried to the upper limits of the stope, and the ore raises extend upward to the grizzly level. If the ore is known to be south of the haulage drift, the transfer drift is driven to the south limit, or a place is prepared so that it can be extended later without risk of damaging the conveyor. The transfer drift is the center line of the stope, stope width being 80 feet with a 40-foot pillar between stopes. After the mill raises and mill sublevels have been completed, the raises are belled out, and actual stoping operations are started at the end of the mill sub around the stope raise, as shown on figures 4 and 5. The stope is carried upward from mining subs spaced at 35-foot intervals, and these are driven to the hanging wall as needed to conform to the stoping cycle. After the last sub has been driven and mining has been started from it, the cycle of operations is such that the miners always have solid ground above them. A 30- to 35-foot pillar, depending on the character of the ground, is usually left above the stope as a floor under the next higher working level.

Little or no pillar extraction has been attempted, and how well the ground will stand without pillars is not known. However, some caving is expected, and, although the completed stopes have not been filled in the past, the management has planned filling as soon as practicable.

Electric Locomotive Haulage

About half of the 1,500 tons of ore produced per day at the Sherwood is transported underground by electric trolley-locomotive rail haulage. Rail transportation is used for both ore and supplies on the 1,000-level, but on the 1,200-level it is used only for supplies, the ore being transported by a belt-conveyor system.

The average haulage distance on the 1,000-level is 2,656 feet per trip, or 1,328 feet with the load. Grade of the track is in favor of the load and is held at 0.5 to 1 percent. Sixty-pound rails with a 24-inch gage are used on both the 1,000 and 1,200 levels. The rails are cross-bonded at irregular intervals. Direct-current power at 250 volts is used on both levels. On the 1,000 level, a 6-ton trolley locomotive with a rated draw-bar pull of 3,000 pounds and a speed of 6.5 m.p.h. is used to pull the nine cars that usually make up the train. The cars are 5-ton Granby type, 7 feet 6 inches long, 3 feet 11 inches wide at the top, and 2 feet 8 inches deep, with a rated volume of 75 cubic feet. They have 16-inch-diameter roller-bearing wheels and a wheel base of 39 inches. Cars are brought to a standstill before dumping to the station pocket, and are then dumped by means of air-operated jacks.

The station pockets have a capacity of 18 to 19 skips, or 110 tons. Ore from the pocket is first drawn into 6-ton measuring pockets and then drawn to the skips. Overcut air-operated gates are used on the pockets of both levels.

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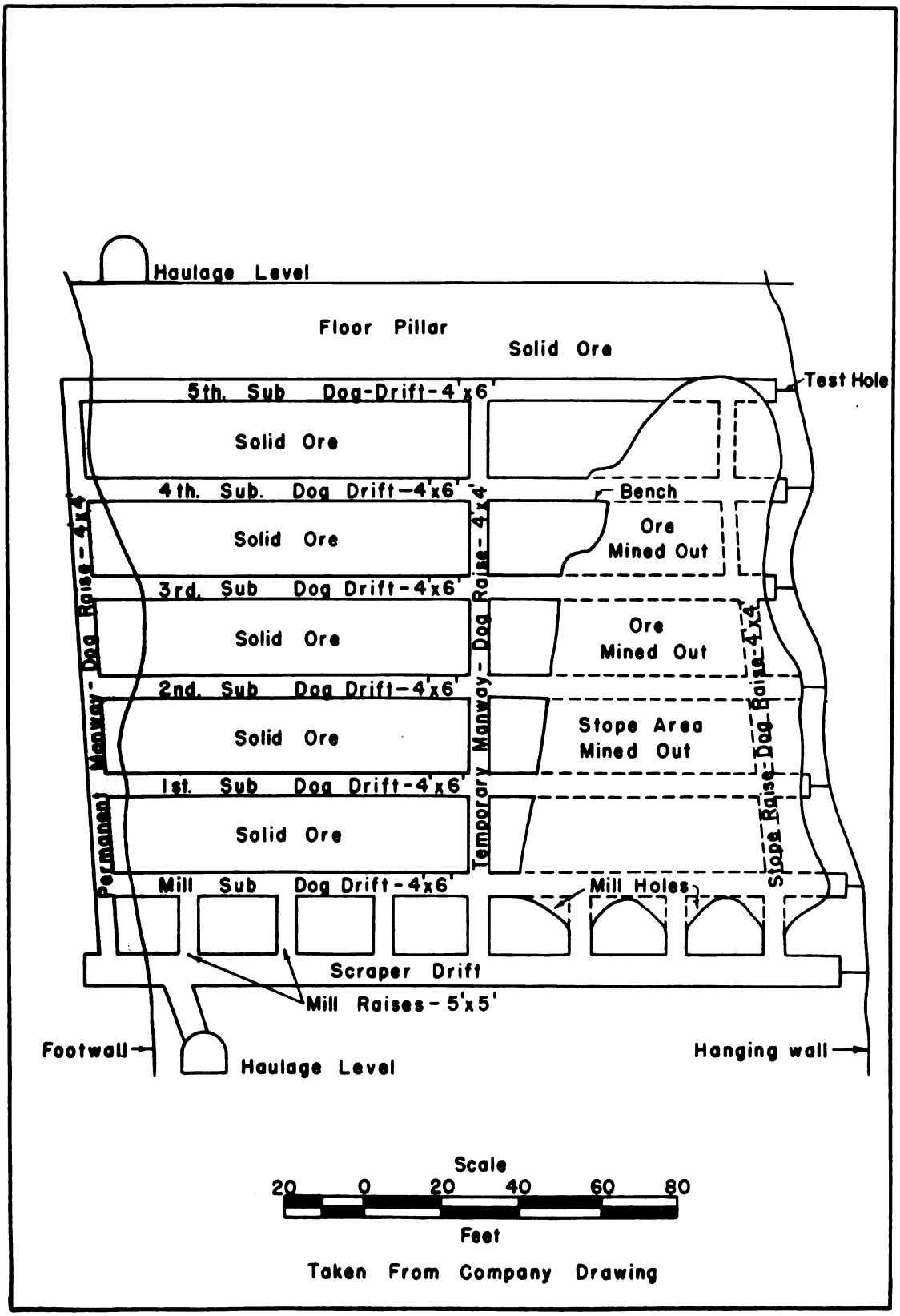

Figure 4. - Typical longitudinal section of stope showing arrangement of scraper drift and mill sub for scraper haulage, Sherwood mine, Iron County, Mich.

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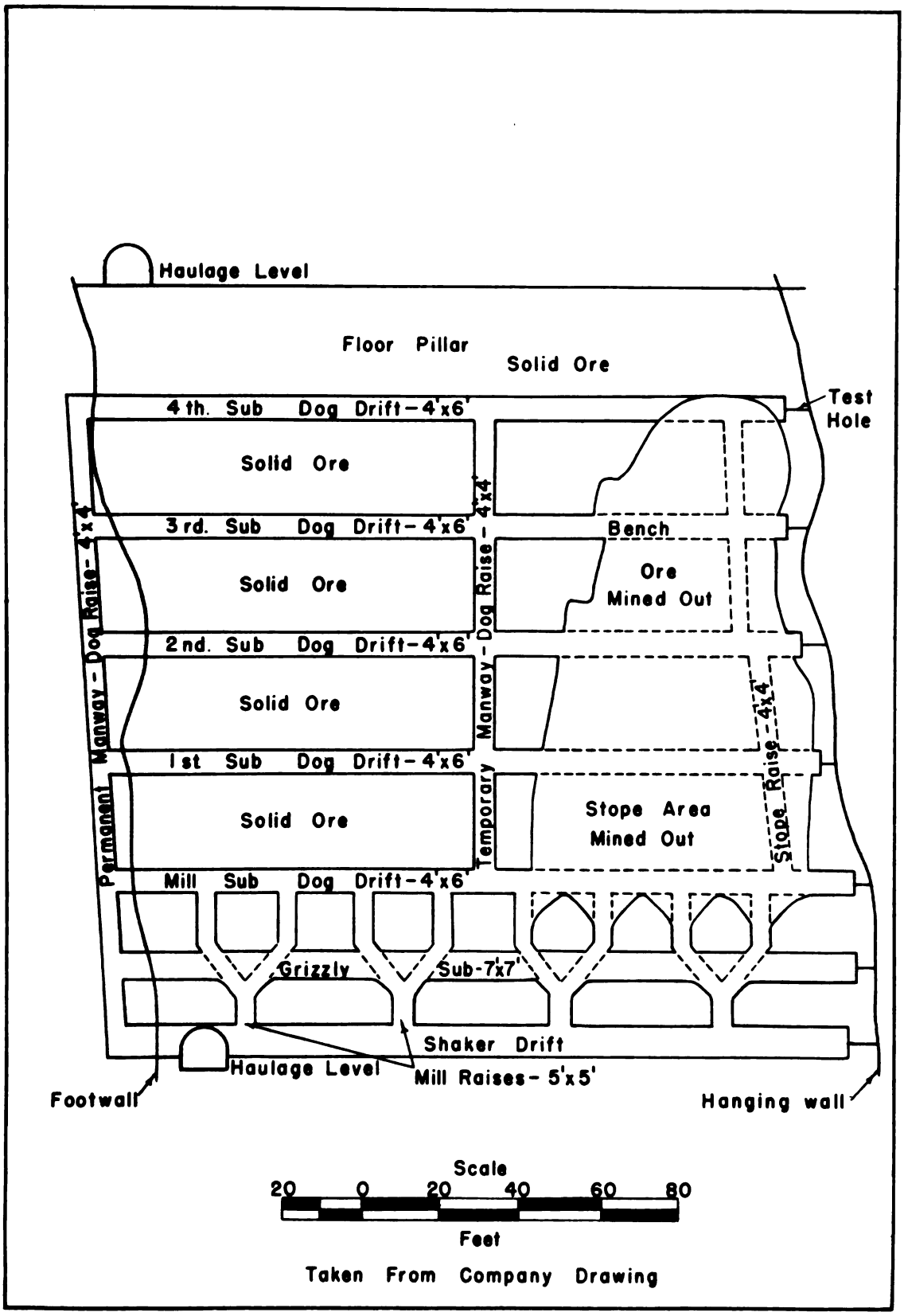

Figure 5. - Typical longitudinal section of stope showing arrangement of shaker drift, grizzly, and mill sub for shaker conveyor installation, Sherwood mine, Iron County, Mich.

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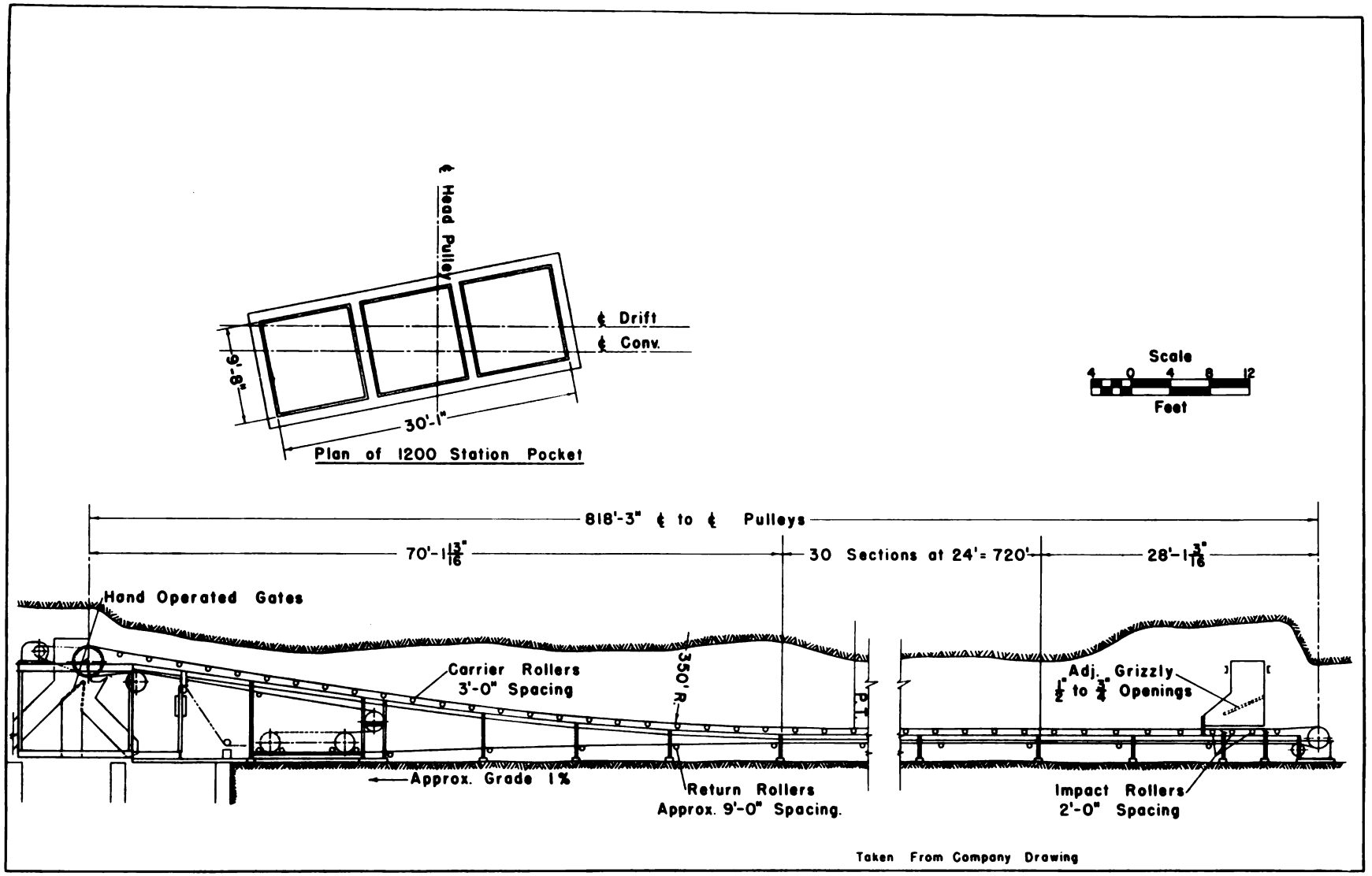

Figure 6. - General arrangement of conveyor 1, Sherwood mine, Iron County, Mich.

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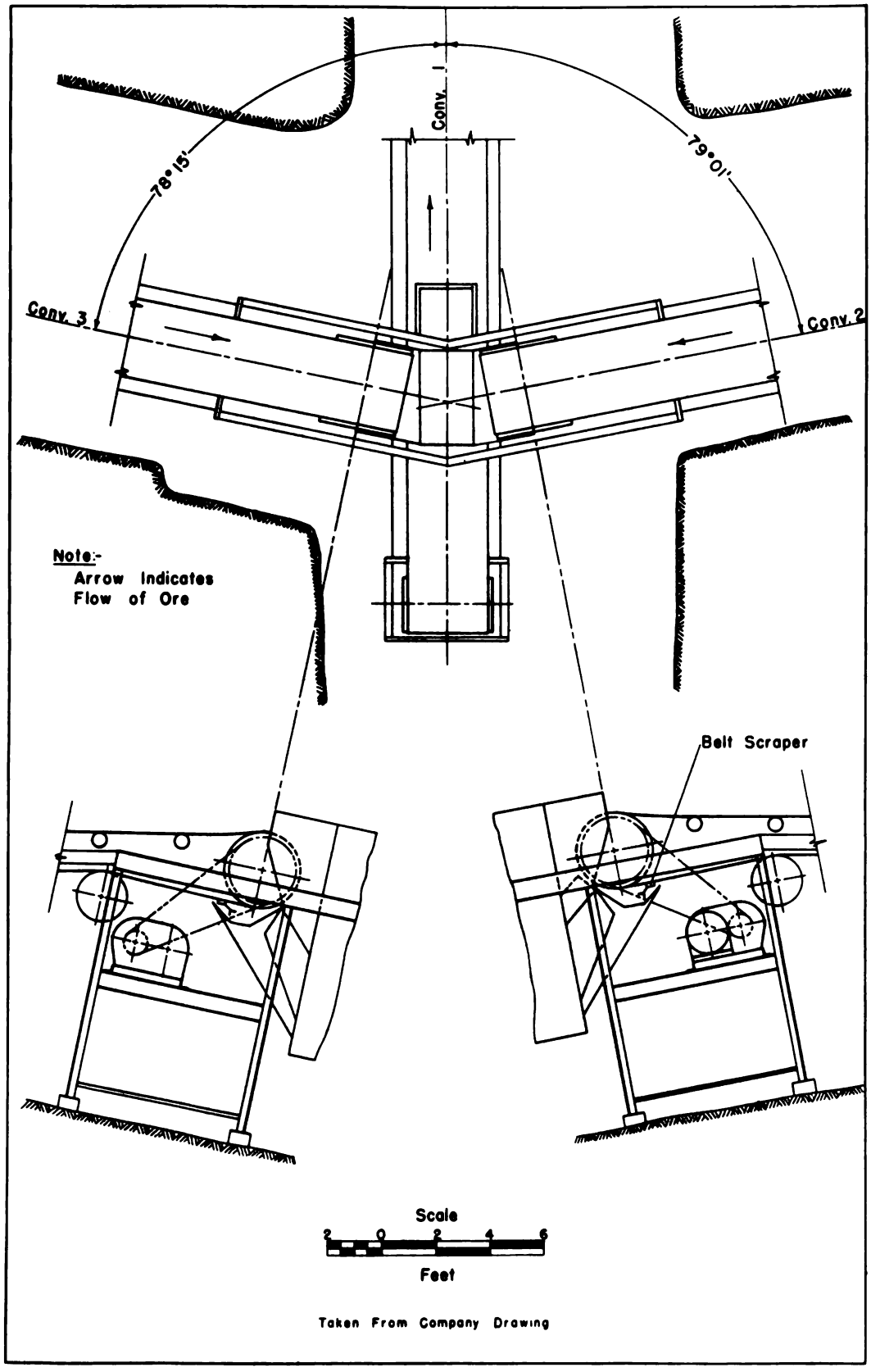

Figure 7. - Junction of conveyors 1, 2, and 3, Sherwood mine, Iron County, Mich.

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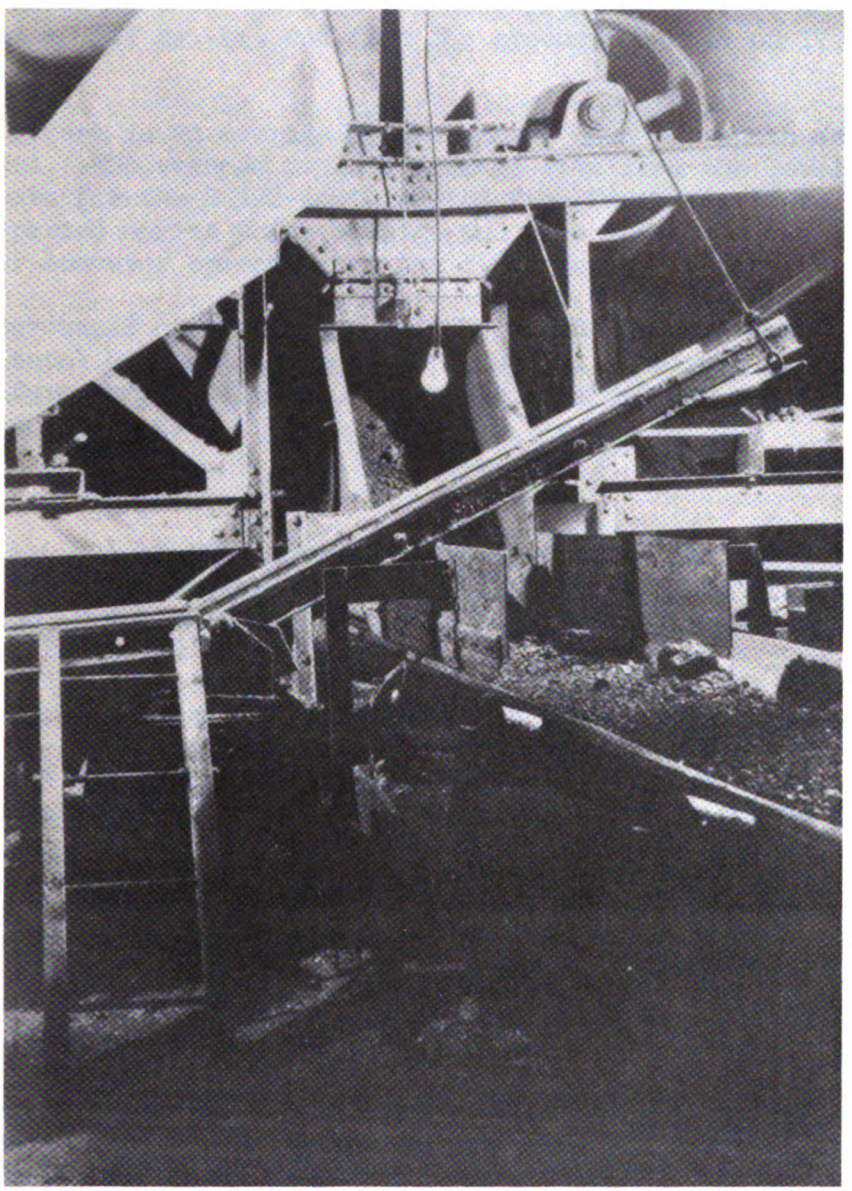

Figure 8. - Junction of conveyors 1, 2, and 3 at Sherwood mine, showing track that can be lowered across conveyor 1 to permit passage between east and west drifts. (Courtesy of Ferris Studio, Iron River, Mich.)

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Hauling on the 1,000 level is done under a labor contract, the crew of 4 men - a motor man, two helpers, and the skip tender - participating in the contract.

Power consumption for ore and supply haulage, with the round-trip haul of 2,656 feet, or 1,328 feet at about 0.5 percent grade with the load, is 0.5638 kw.-hr. per long ton. This is computed from the average monthly consumption rate of 10,017 kw.-hr. and from the production rate of 17,768 long tons per month.

The power figure is an average of the amount used per month as taken over a 10-month period. The average monthly tonnage rate from the level was obtained from talley sheets for the 2 1/2-month period from September 16 to December 1, 1947, the same period during which tonnage and time records were kept on the belt- and shaker-conveyor operation on the 1,200 level.

Power is purchased on a sliding schedule based upon the maximum peak load demand and the total kilowatt-hours used per month. The rate charged per kilowatt-hour therefore varies slightly from month to month but averages $0.01397 per kilowatt-hour.

Belt Conveyors

A general lay-out of the conveyor installations on the 1,200 level, with the location of both the shakers and belt units, is shown in figure 1. The relative position of the belt conveyors and supply track is shown in the sectional views, figures 2 and 3.

The belt-conveyor installation consists of three units, designated 1, 2, and 3, a three-way discharge chute at the shaft pocket, and a transfer chute at the junction of the units. Four loading hoppers or chutes for transferring ore from the shaker conveyor to the belt were built and installed by the mining company.

The belts are 36 inches wide and 13/16 inch thick. They are 4-ply, 42-ounce duck with two breaker strips, one at 3/16 inch below the top and the other just above the fabric. The top cover thickness is 11/32 inch, and the bottom cover is 1/16 inch thick. Cover material is Buna No. 1 synthetic rubber with a skim coat for milldew protection.

Conveyor 1, installed in the main or north-south crosscut, is 818 feet 3 inches in length; conveyor 2, in the east drift, is 645 feet long. No. 3 unit, as originally ordered for the west drift, was 635 feet long; however, this was later reduced to 610 feet. All measurements are the distance between center lines of the head and tail pulleys. The total length of the units as installed is 2,073 feet. The conveyors are the snub-drive type, and, except for the arrangement at the discharge chute of No. 1 and at the junction of Nos. 1, 2, and 3, shown on figures 6, 7, and 8, they are almost identical in construction. They are designed for a speed of 200 feet per minute with a load of 250 tons per hour of ore weighing 125 pounds per cubic foot. Each unit is driven by a 20-horsepower, splash-proof, ball-bearing, induction motor operating on 440-volt, 3-phase, 60-cycle, alternating current. Motor speeds are 1,760 r.p.m.

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A herringbone gear-speed reducer with a reduction ratio of 28.7 to 1, coupled to the motor with a flexible coupling, transmits the power by means of a chain and sprocket drive to a 4-7/16-inch head pulley shaft. The head pulleys, which are lagged, are 36 inches in diameter and 38 inches across the face. Diameters of the snubbing and tail pulleys are 24 inches. Belt elevating pulleys just ahead of the tail pulleys are 18 inches in diameter.

The heavily constructed conveyor frames or sections are made up in 24-foot lengths. Runners are 6-inch, 8.2-pound channel irons braced at 4-foot intervals with 5-inch, 6.7-pound channels. Frames are supported by, and bracing is constructed from, 2 by 1/4-inch angle irons. Decking is of 12-gage steel plate. A sectional view of the frames is shown in figure 9.

Ball-bearing carrier and return rollers are used on all units. The carrier rollers, three to a set, are 5 inches in diameter and 13-1/2 inches long, with two outside rollers set at an angle of 20 degrees to the horizontal. Return rollers are 5 inches in diameter and 38 inches long. Rubber impact carriers are used at all loading points. Carrier rollers are spaced on 3-foot centers. A 9-foot spacing is used for the return rollers and a 3-foot spacing is used for the impact carriers. All rollers have alemite fittings for greasing and are serviced about every 6 months.

Details of the discharge chutes at the head end of Nos. 1, 2, and 3 belts, together with the arrangements of the drives for the three units, are shown in figures 6 and 7.

Figure 8 is a view of the chute at the head end of Nos. 2 and 3, showing the arrangement for track cross-over of the No. 1 unit.

Magnetic type line starters with push button controls are used for starting and stopping the belts. These are connected to permit starting or stopping the entire conveyor system from main control points located at the shaft and at the junction of the conveyor units. Stopping No. 1 unit also stops either or both Nos. 2 and 3 units, as well as the shakers feeding them. Neither No. 2 or No. 3 can be started without starting No. 1; however, they can be stopped separately. Stopping No. 2 or No. 3 unit automatically cuts off power to the shaker conveyors, as do the main control switches at the shaft and the junction.

An additional safety switch for cutting out Nos. 2 and 3 units was later installed by the mining company on the discharge chute at the junction of Nos. 1, 2, and 3 units. This is a solenoid switch attached near the top of the chute, so that any build up of ore in the chute to this point forces the switch and stops Nos. 2 or 3 conveyors and also stops the shakers. The switch is shown on figure 8 just above the light bulb.

Installation of Belt Conveyors

In preparing the 1,200 level for belt conveyor haulage, the first step was to establish the center lines for the three units. The track was then moved, and the back of the station and the level at the shaft and at the junction were enlarged to accommodate the chutes and to allow for the upward

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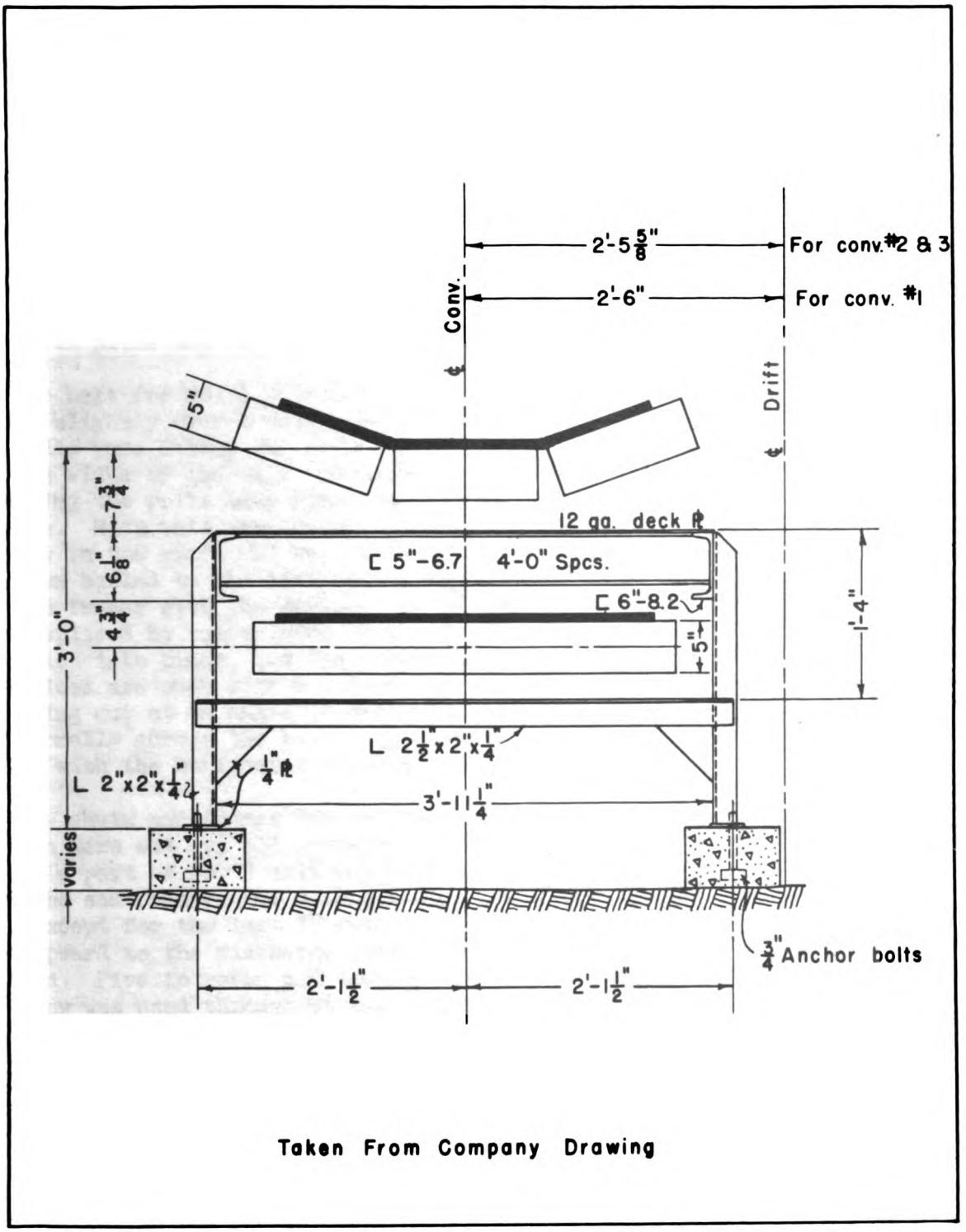

Taken From Company Drawing

Figure 9. - Typical conveyor section, Sherwood mine, Iron County, Mich.

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slope of the conveyors to the chutes. Upon completion of this work, center-line points and grade marks were put in at regular intervals along the back and side of the level.

Installation was started in July 1946. The discharge-chute pieces and the drive pulley frames of No. 1 unit, which were factory-marked for fitting, as were all the frame sections, were the first pieces to be erected, and those with 3-frame sections were alined and set permanently before erection of other sections was begun. Erection proceeded by setting up 3 or 4 succeeding frames, bolting them together, and blocking all into approximate position at one time. The forms for concrete pedestals then were put in at each support, the frames were blocked to final line and grade, and the concrete pedestals poured. After the last frame section had been erected and the tail pulley set, all that remained to complete erection of the unit was to bolt the carrier and return rollers in place and to install the belt.

The belt for No. 1 unit was in two rolls - one, with 667 feet of belt, weighed slightly over 4 tons, and the other, with 1,023 feet, weighed 6 tons. Both rolls were bulky, the diameter of the larger being only a few inches less than the width of the cage compartment. Because of the weight and necessity for having the rolls hang free, two slings were used to suspend them beneath the cage. With this arrangement, the rolls were safely suspended and hung squarely in the shaft and were lowered to the level without difficulty. They were then hauled to the tail end of the conveyor, and from there were pulled onto the frames with the trolley locomotive. After one length had been unrolled, it was spliced by vulcanizing to the second piece; then the full length of belt was pulled into place, and the ends were joined with another vulcanized splice. The splices are made with a 3-foot lap of the ends and in several layers, the ends being cut at an angle of about 78 degrees with the long axis of the belt, or diagonally across the belt. The belt was then tightened to the desired tension with the horizontal take-up.

The chute and frames for the head ends of Nos. 2 and 3 units at the junction were set up, and erection of No. 2 unit began. After this was completed, a part of No. 3 unit was installed. All three units were erected in about the same manner and were set at a grade of 1 percent in favor of the load, except for the last 77 feet at each head pulley end. Here the conveyors slope upward to the discharge chute and the grade is about 11 percent against the load. Five to seven men usually made up the erecting crew, and about the same crew was used throughout the entire job.

Belt-Conveyor Operation

The entire length of No. 3 unit was not erected at one time, as the west drift had been completed for only a distance of 400 feet when conveyor haulage was installed, and the final length was to be about 640 feet. The remaining 240 feet was driven by using a scraper and a slide in conjunction with the conveyor for moving the broken ore from the face to No. 1 belt. Because of the distance for scraping and considerable water in the drift, slushing operations were slow but generally rapid enough to permit blasting a round each shift.

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After the drift had been driven to its full length, the conveyor was extended and finally was installed, the distance between center line of head and tail pulleys being 610 feet. Up to the present, the No. 3 unit has been used only in conjunction with scrapers for handling development spoil from the 1,200 west drift and the few feet of transfer drifts that have been driven so far.

At the present time the No. 2 unit in the east drift is handling ore from four stopes at the total rate of about 750 tons per day. The ore, after being worked through a 9-inch grizzly into the shaker loading chutes, is moved by shaker conveyor (which will be described later in this paper) to the belt, where it is loaded by means of a specially constructed loading hopper or chute shown in figures 10 and 11. From the loading points it is carried to the transfer chute at the junction of the three units and conveyed on No. 1 unit to the shaft pocket.

In designing the loading hopper or chute for the belt conveyor, several factors had to be considered; the chute had to prevent spill, load to the center of the belt, and be free to move upward in order to permit boulders to pass without hanging up and digging into the belt. Similarly, the chute had to be strong enough to withstand sustained pounding by boulders weighing up to 100 or 150 pounds. Figures 10 and 11 show the details of one of the first chutes designed by the company. A few modifications in construction have been made in later designs, but the working principal is the same in each case. The chutes are relatively simple to construct and can be installed or moved quickly. They have been found to function well. It is important that the flow of material be directed as close to the center of the belt as possible This is accomplished by making a V- or U-shaped cut in the lip as far back as necessary to obtain the exact point of discharge for centering the material on the belt.

All stoping on the 1,000 and 1,200 levels is done under labor contracts based upon the tonnage hoisted from each contract place during a 2-week pay period. On the 1,000 level, where locomotive haulage is used, it is a simple matter to obtain an accurate tonnage figure for ore coming from the contract places. Cars from each contract place are tallied separately, the total number of skips hoisted being a check against the car talley.

On the 1,200 level, however, with shakers operating at intermittent intervals and ore at the pocket being any combination of tonnages from the four shakers that are used in the separate contracts, there was no way of obtaining an accurate measurement for settlement other than by stope measurement. The management, in attempting to solve this problem, started on September 16, 1947 to keep a record of the operating time for each shaker. This is accomplished by having the belt-conveyor operators log starting and stopping times and estimate the number of skips coming from each contract place. A record of the actual number of skips hoisted from the level is kept by the hoistman as well as the skip tender. The skip talley checks closely with the conveyor operator's tonnage estimate, which is made by using a factor based upon operating time and type of ore - fine, medium, or coarse coming from the individual contracts. The factor was obtained by timing the shakers for each type of ore and then measuring this ore by skips hoisted. By timing and measuring the

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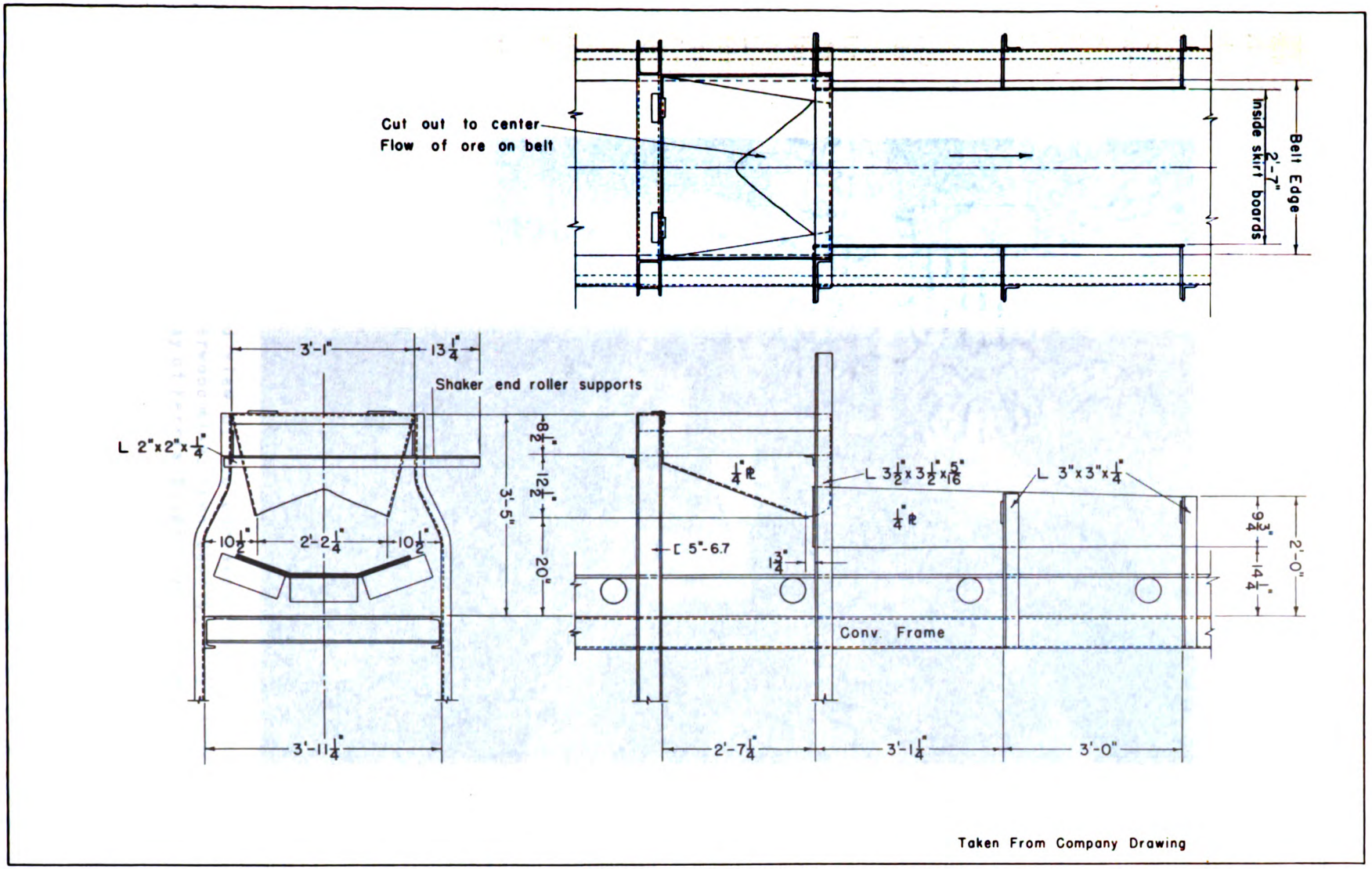

Figure 10. - Belt conveyor loading chute, Sherwood mine, Iron County, Mich.

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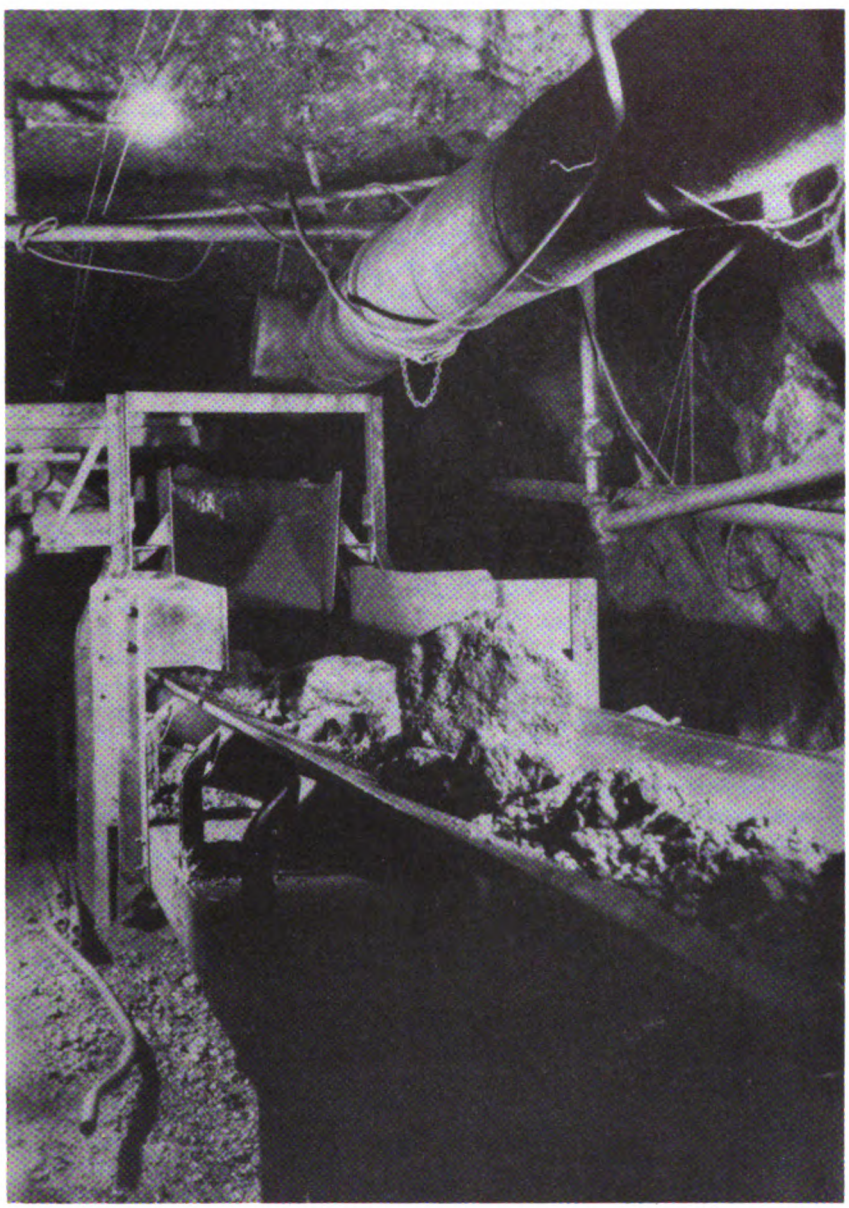

Figure 11. - End view of the conveyor loading chute, Sherwood mine, Iron County, Mich. (Courtesy of Ferris Studio, Iron River, Mich.)

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same type of ore a sufficient number of times, a fairly reliable factor resulted. Although the method of measuring is somewhat empirical, it has worked satisfactorily to date for all concerned.

At this writing, the belt conveyors have not operated full time nor at capacity, except for short intervals. Average operating time per shift, taken over 2-1/2 months, is 3 hours and 39 minutes; and during this time the tonnage handled has ranged up to 400 tons per hour, averaging 215 tons per hour, or 35 tons short of the rated capacity of 250 tons. The belts could easily handle a considerable overload for short periods without damage to either mechanism or belts.

Power consumption, as calculated from readings taken with an industrializer, which in turn were compared with meter readings, is 0.12 kw-hr per ton. The power used for supply haulage is not included in this figure.

Shaker Conveyors, Operation

Prior to 1943, hoe-type scrapers powered by double-drum scraper hoists were used in all stopes at the Sherwood mine. These were essential equipment for sublevel stoping and were the only means then used to transfer the ore from the mill raises to the main haulage ore chutes.

In most stopes, as shown on figure 4, broken ore had to be moved through distances as great as 150 and 200 feet, and in one the length of haul exceeded 250 feet. For hauls of such distance the scraper proved to be too slow for an efficient stope operation, and in seeking a faster and less costly method for moving the ore, the management decided to try the shaker conveyor.3/ Shortly thereafter the first shaker unit was installed in a stope on the 1,000 level where the scraping distance was greatest, in this instance being 240 feet. Accurate cost records were kept on the shaker operation, and in about a year after installation the data were compiled and costs for the shaker and scraper were compared.

The results3/ indicated that the cost of moving ore in the stopes was lower when shaker equipment was used. The principal factor contributing to the lower cost was the capacity of the shaker, which could move approximately 120 tons per hour, whereas the scraper had to be operated almost continuously for an entire shift to move the same amount. Another advantage of using shaker conveyors, particularly in wet transfer sub-drifts, is that drainage is simplified and mixing of ore and water usually can be avoided. When scrapers are used it is difficult to prevent some mixing of ore and water and the resulting "soupy" mixture not only slows scraper operation but causes delay in loading and dumping tram cars and skips.

After the first shaker unit had been in operation about a year, another unit was installed in another 1,000-level stope. The satisfactory service

3/ Satterley, R. D., Shaker Conveyors in Sub-Level Stoping in an Iron Ore Mine: A.I.M.E. Min. Technol. Tech. Pub. No. 1823, Class A Metal Mining No. 120, May 1945.

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given by both units convinced the management that the shaker could be used to advantage in the 1,200-level stoping operations where the belt conveyor haulage system was to be installed. Both shaker units were later moved to transfer drifts off the east drift of the 1,200 level, one being moved late in 1946, when the belt conveyor was installed, and the other in 1947. Still later, a third unit was placed in operation, and recently the fourth unit was installed. All shakers are now being used in the stopes off the 1,200 east drift for the purpose of transferring the ore from stopes to the belt conveyor.

Installation of a shaker conveyor presents no unusual problem. After the transfer drift has been completed and cleaned up and stope development is sufficiently advanced, the line and grade for the shaker is established. The center line of the shaker is usually set at 2-1/2 feet from the chute side of the transfer drift. This permits building chutes with the proper slope and enough clearance between the wall and the shaker for ample working space. Clearance between the end of the discharge trough and the chute loading to the belt is a determining factor. In establishing the grade of the shaker troughs, as shown in figures 10 and 11, this clearance should be sufficient to permit raising the chute at least 4 to 6 inches and at the same time not have it strike the trough should a boulder on the belt cause the chute to rise. When using the top of the discharge chute for establishing grade of the troughs, considerable leeway is permitted by the adjustments on the drive unit. The elevation of the discharge chute being fixed, the drive unit is raised or lowered until the desired grade, usually 1 percent in favor of the load, can be obtained by adjusting the unit trough. Position of the drive unit with relation to the shaker-loading chute and discharge chute for loading the belt conveyor is shown in figure 12.

After the drive unit is set in place, four ratchet jacks are used for holding the unit in position, and the connecting or unit trough is then placed and adjusted for grade. Construction of loading chutes, wiring, and controls proceeds at the same time. Under normal conditions, 5 to 7 days are required for installing the unit and troughs, for construction of the chutes, and for miscellaneous work connected with the installation.

The four shaker conveyors now in use are equipped with an "underneath" drive. Connecting or unit trough is directly above the drive unit. Two of the units have 20-horsepower and two have 30-horsepower motors of the line-start induction type powered by 3-phase, 60-cycle, alternating current at 220 or 440 volts and drawing 39 or 18 amperes, respectively, at full load. Motor speed is 1,160 r.p.m. Adjustments for the strokes per minute and for the length of the stroke are usually set at the maximum - in this case, a 9-inch stroke at 80 strokes per minute, which gives the best results with the type of ore handled at the Sherwood. Goodman Type M, size 3 troughs with a sectional area of 115.56 square inches, in 10-foot lengths, are used in all units. They are purchased unlined, but a special steel lining 3/16 inch thick is spot-welded to the surface at the mine. Each trough moves and is supported on a set of Ray-type rollers. Supports consist of an upper and lower frame. The upper, which is welded to the trough, has the track or guides for the wheels; the lower frame holds the axle and roller-bearing wheels and is bolted to the top of the timber that supports the frames and troughs.

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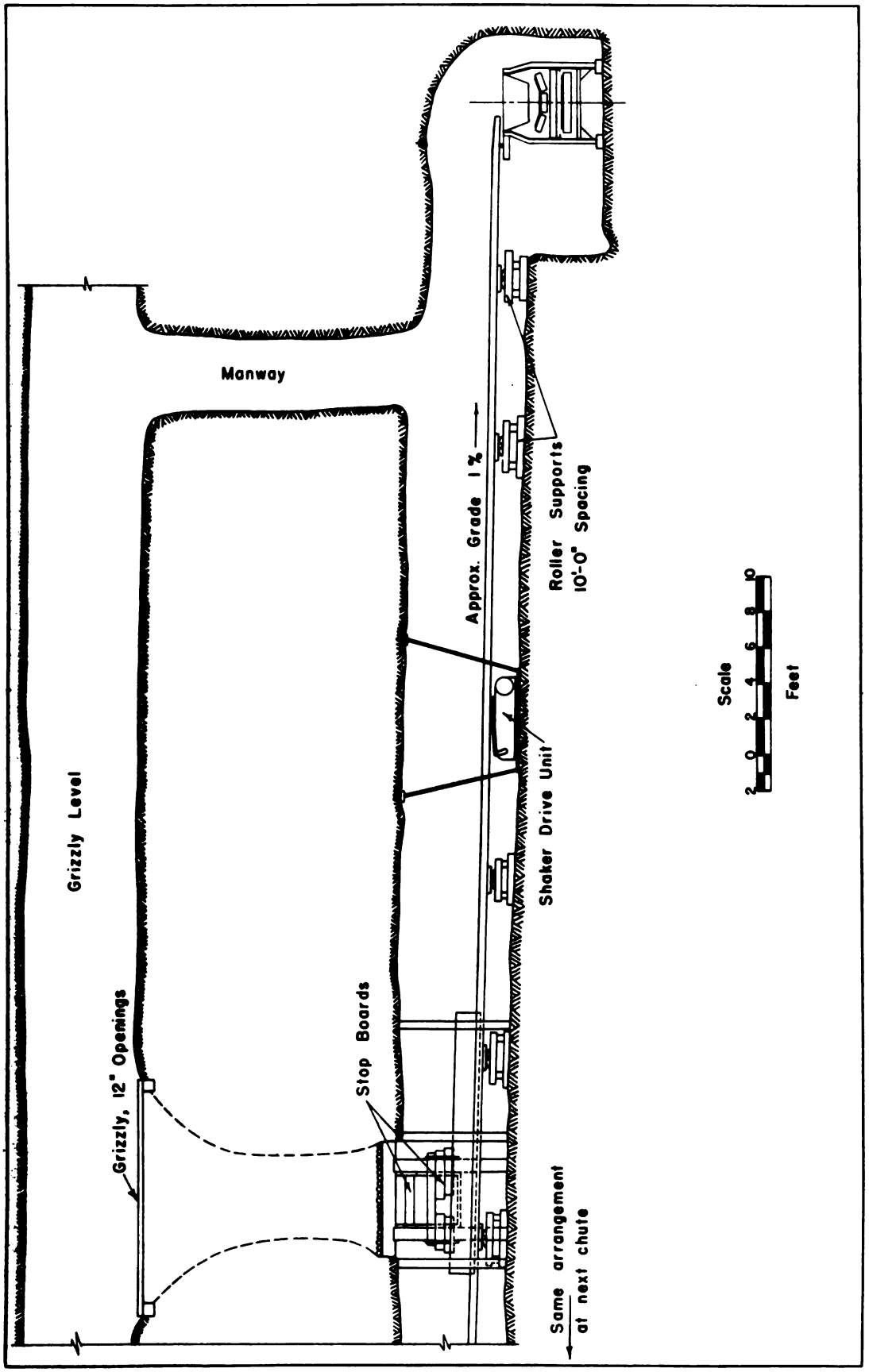

Figure 12. - Typical shaker conveyor installation, Sherwood mine, Iron County, Mich.

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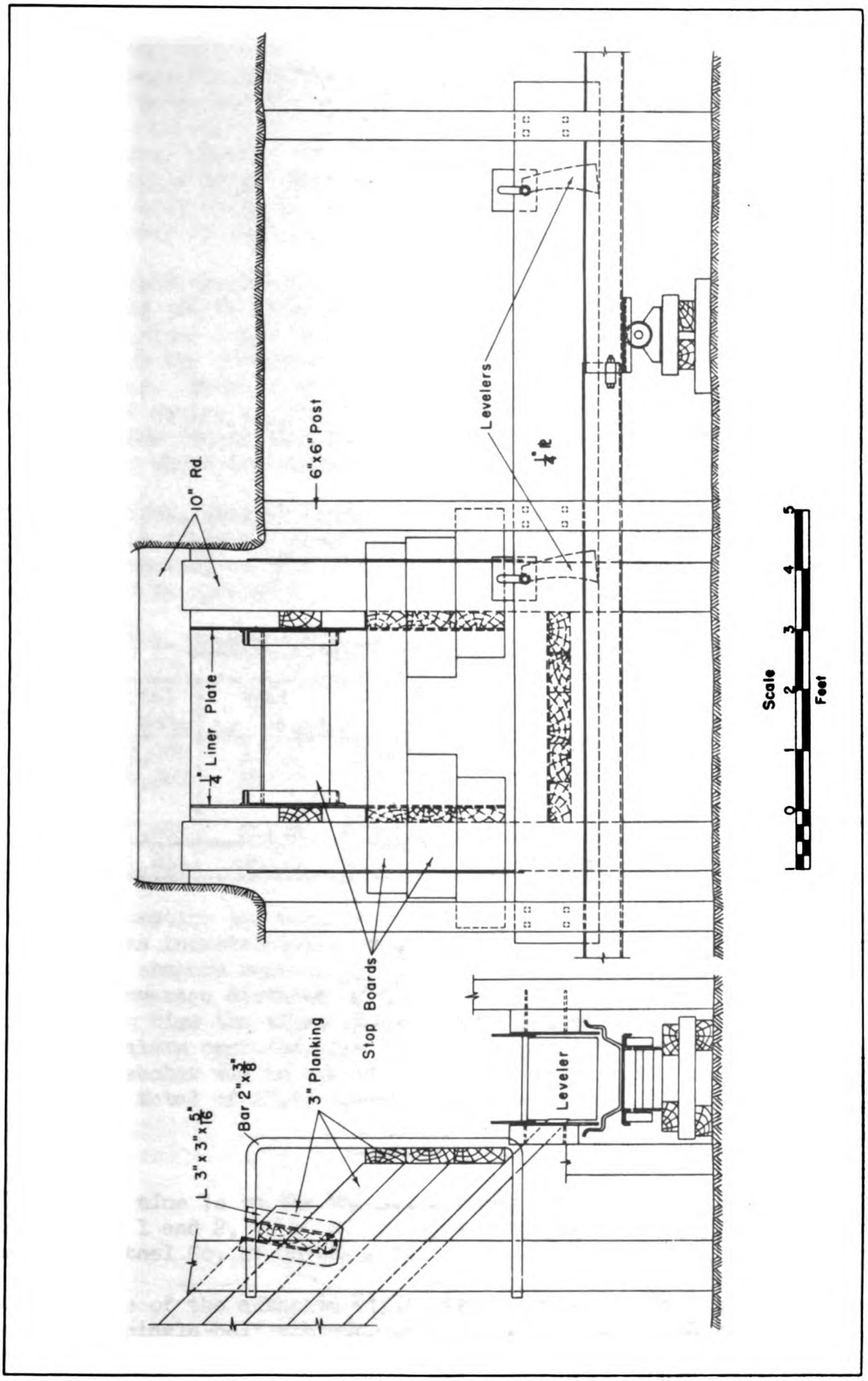

Figure 13. - Shaker conveyor loading chute, Sherwood mine, Iron County, Mich.

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Figure 1 shows the location of the drifts where shakers are in operation and their relation to the 1,200 east drift. The 9 percent moisture of the ore and the fineness to which it generally breaks make it good material for shaker conveying. Coarse "chunky" ore shakes well but is harder on the troughs, especially during loading. Runs of all coarse material occur only occasionally, and most of the ore, which is put through a 9-inch grizzly before reaching the shaker, is 3 inches or smaller in size.

Loading chutes are of conventional type, with board stoppers for gates. Steel plate-lined side boards are built up to a height of 13 inches above the shaker and extend 1-1/2 feet along the shaker from the upgrade side and about 8 feet from the downgrade side of the chute or toward the discharge end of the shaker. Details of the shaker loading chute and hopper are shown in figure 13. A device called a "leveler," which is used for spreading or flattening out the ore in the trough in order to prevent spillage from overloading, is also shown in figure 13.

Operating time, shaking distances, and tonnages are given for the individual shakers in table 1. These data were obtained from company records kept for 2-1/2 months, or 58 working shifts, but include only three of the four shakers now in operation.

TABLE 1. Shaker conveyor operation data, Sherwood mine

Shaker	Total tons	Tons per shift	Total hours	Hours per shift	Tons per hour	Shaking distance
19	17,970	309.8	105 hr. 7 m.	1 hr. 49 m.	171.0	70
21	14,262	246.9	122 hr. 25 m.	2 hr. 7 m.	116.5	200 132
23	11,682	201.4	73 hr. 26 m.	1 hr. 16 m.	159.0	60
Average	43,914	252.7		1 hr. 44 m.	145.9	107.3

Power consumption has been calculated from readings taken at 2-minute intervals with an industrializer over a 2-hour and 24-minute period. During the period, the shakers were in operation 1 hour and 38 minutes and moved 270 tons of ore an average distance of 90.5 feet. In the 1 hour and 38 minutes actual operating time the three shakers were operating together for only 4 minutes; two shakers operated together for 45 minutes, and for the remaining 49 minutes one shaker was in operation. The average power consumption was 16.92 kw., or a total of 27.63 kw-hr, during the operating period.

MORRIS MINE

The Morris mine is on the Marquette Range, 5.5 miles west of Ishpeming, Mich., in secs. 1 and 2, T. 47 N., R. 28 W., Marquette County. It is operated by the Inland Steel Co. of Chicago, Ill.

At the time of the author's visit, the conveyor installation at this mine consisted of a single-belt conveyor unit 30 feet long, which was operated in conjunction with a scraper for moving broken ore in a transfer drift.

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This method for moving ore in transfer drifts was being tried entirely as an experiment, and the conveyor installation, which was made in cooperation with the manufacturer, was just another step taken by the company in an effort to obtain a more efficient over-all operation.

At the time the mine was visited, the belt and scraper arrangement had been installed for only a very short time and no operational data were available.

Shortly after the author had been at the Morris mine, it was learned that the experimental work with the belt was discontinued and the conveyor removed from the mine.

JAMES MINE

The James mine is on the Menominee Range in the vicinity of Iron River, Iron County, Mich.

In 1943, Pickands Mather & Co., in planning the development of several somewhat isolated blocks of ore, considered the use of shaker conveyors as a possible means of reducing the amount of prestoping development that would be required to reach and mine these blocks.

It was known that a considerable amount of "dead work," mainly through barren ground, would be necessary if the blocks were to be developed and mined by using the conventional scraper and trolley locomotive haulage. By using shaker conveyors as the intermediate step in transferring ore from a stope to main haulage ore raises, it was calculated that several hundred feet of drifting and raising could be eliminated and that possibly more efficient stoping operation could be maintained. It was determined that conveyor-unit costs would be no more than that involved in the "dead work" and, in addition, the units would have a salvage value or could be used again if they proved efficient for similar stoping operations elsewhere. With the foregoing conditions in mind, development of two blocks of ore, employing shaker haulage in transfer drifts, was initiated, and two units were installed late in 1943.

To date the shakers have transported about 160,000 tons of iron ore. They have proved to be more efficient than the scraper for transporting ore over long distances and, as expected, have effected a considerable saving in the amount of development required to reach and prepare the blocks for stoping.

At the present writing, only one shaker unit is in operation, the other having been removed when the block, where it was installed, was mined out.

Description of the Deposit

The ore deposits of the James, as in other mines in the district, occur in the highly folded, iron-bearing, Upper Huronian formation. The formation, comprising several ore-bearing beds interbedded with slate, is in the Michigamme slate, a member of the Upper Huronian series of rocks found in the Iron River district and other parts of the Menominee Range.

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The strike of the ore deposits is almost east-west, or approximately parallel to the general trend of the ore-bearing formation. The dip of the formation is almost vertical but varies slightly to steeply north or south, whereas the dip of the ore bodies, because of folding, varies considerably and is relatively flat.

The iron formation is composed of ferruginous cherts and slates and iron ore. The principal ore minerals are hematite and limonite.

A typical analysis of ore shipped from the James mine is as follows:

Analysis, percent - natural

Fe	P	SiO_2	Mn	Al_2O_3	CaO	Mg	S	Ignition loss	Moisture
52.58	0.398	7.15	0.20	1.53	0.30	0.24	0.027	9.07	5.85

Generally, the ore is porous and of medium hardness; however, both extremely hard and soft ribs occur and are not uncommon. The ore has been highly fractured by folding and breaks relatively fine, except for the bands or ribs of hard ore that break into boulders that require some secondary blasting. For the most part, the ore, regardless of fracturing and its medium hardness, stands well and permits mining over a fairly large area without support. However, subsequent pillar removal has caused considerable caving in the old workings.

The ore-bearing formation has been mined along the strike for a distance of about 2,000 feet. At present, mining operations are carried on throughout a lateral distance of about 1,300 feet. Normal thickness of the ore bodies is 60 feet from hanging to footwall, but, owing to their dip and attitude, an average stoping width of about 200 feet can be obtained, and at times the stope width has been 300 feet or more.

A black pyritiferous slate usually marks the limits of the ore on both the hanging and footwall. In places along the hanging wall a thin bed of cherty iron-bearing rock, locally called "iron formation," occurs in contact with the ore.

Production

The daily production rate is between 1,100 and 1,200 tons, or about 327,000 tons per year. During 1947, 305,000 tons was shipped, the remaining 22,000 tons having been stock-piled at the mine. One hundred men are employed underground and on the surface. Of these, 40 are on production, including mining and development, 25 are sinking the shaft and developing a new 7th level station, and 30 to 35 men make up the surface crew. The underground production and surface crew work one shift per day. Shaft work and work on the 7th level are on a 3-shift basis.

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Hoisting

Access to the mine is through a vertical, 4-compartment shaft 938 feet in depth. Timber sets and lagging are used throughout. The shaft is 6 feet by 16 feet inside the sets and is divided into four compartments - two skip compartments, a cage compartment, a manway, and a slot for the cage counterweight.

Single cylindrical drum hoists are used for both the skips and the cage. The ore hoist has a drum diameter of 6 feet and a face width of 7 feet. It is driven by a 400 horsepower induction motor using 3-phase, 60-cycle alternating current at 2,200 volts. Speed of the motor is 490 r.p.m. The cage hoist is also a cylindrical drum-type Nordberg with a drum diameter of 5 feet and a face width of 6 feet. The hoist is driven by an induction motor rated at 100-horsepower and using 3-phase, 60-cycle alternating current at 2,200 volts. Motor speed is 570 r.p.m. at full load.

Both skip and cage hoists employ 1-inch diameter, 6 by 19-strand ropes that wind over and under on the drums. Skips are in balance, and a counterweight is the cage balance. Both hoists are equipped with air-operated brakes, an extra hand brake being used on the cage hoist. Lily safety controls prevent overwind.

Steel skips weighing 4,200 pounds are used. They are 24-1/2 by 52 by 90 inches inside and have a capacity of 67 cubic feet, or 3-1/2 tons. The cage, also of steel, weighs about 6,250 pounds and holds 20 men.

Hoisting speed of the skip is 1,200 feet per minute and of the cage is 750 feet per minute.

Mining Methods

The principal working levels at present are at 516, 666, and 866 feet below the collar of the shaft and are designated the 5th, 6th, and 7th levels, respectively. Levels are extended from the shaft for about 2,600 feet in the general direction of the strike of the ore-bearing beds.

Most stoping is done from the 6th, or main, haulage level and is confined to the ore bodies that have been blocked out between this and the 5th level. No work is being done from the 5th level to the surface. Below the 6th level, work consists of preparation of the 7th level station and shaft pocket for eventual installation of the crusher and rotary car dump now being used on the 6th. As soon as the 7th level has been developed, it will be extended and will serve as the main haulage level.

At present, two stoping methods - the sublevel and the "scram" - are used, the choice depending principally on the size and location of the ore bodies. The larger and more regular or main blocks of ore are mined by the sublevel method. Scram stoping, or "scramming," which is a term for radial top slicing without timber, is used for recovering pillars and the smaller or less isolated ore bodies that bulge from the main blocks.

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Shaker conveyors were installed for mining ore bodies that lie outside the principal stoping areas. The shaker now in operation is used for transferring ore from stopes in a block on the north side of the 5th level and extending vertically from a short distance above to about 50 feet below the 5th.

In developing this block, which is roughly 300 feet long, 200 feet wide, and about 60 feet thick, a 4 by 4-foot manway and an ore chute of the same dimensions were started from the 6th level, at one end of the block, and raised 75 feet to the height at which the transfer sublevel or shaker drift was to be driven. The shaker drift was then advanced along the strike and near the center of the block to the limits of the stoping area, a distance of about 300 feet.

Three 4- by 5-foot raises spaced 90, 195, and 260 feet from the ore chute were then raised 25 feet to the grizzly sublevel. The raises have a 12-inch grizzly at the top and are used to load the shaker. Chutes are of conventional design, with a 3-foot opening and ordinary stop-board gates; the bottom is sloped at about 45 degrees. A manway near the last chute is also carried up to the grizzly sublevel. Following completion of shaker loading chutes, the grizzly sublevel is driven about 25 feet above the shaker sublevel, and from this the scraper subs, each 6 by 8 feet in section, are driven off at right angles to the limits of the ore block on both sides of grizzly sublevel. The scraper sublevels are spaced on 95- to 100-foot centers, which permitts an 80-foot stope width and a 10-foot pillar between stopes. From these sublevels, the mill raises, staggered and spaced on 20-foot centers, are driven to the mining sublevel, and actual stoping begins. Mining sublevels usually are driven at vertical intervals of 35 feet, but this is somewhat dependent on the thickness of the block and the size of floor pillar to be left, if required, for support of a level or workings above the block.

Occasionally, the pillars between stopes are removed as the stope retreats. In other instances they are left for support until the area has been mined out, at which time they are blasted or cave unaided.

Long-hole drilling to a depth of 35 feet and more is standard practice wherever conditions permit. Jackhammer or sinking drills mounted on jack legs are used for most drilling in stopes and stope development headings. Stopers are used for raising. The 10- by 10-foot main haulage levels are drilled with drifters. Detachable bits with 7/8-inch hexagonal steel for the jackhammer and 1-1/4-inch steel for the drifters are standard equipment. Blasting is done with three types of powder of different strength and sizes; 65 percent ammonia gelatin in 1-1/4- by 8-inch, and 2- by 28-inch sticks is used in extremely hard ground, 45 percent gelatin in 1-1/4-inch by 8-inch sticks and a 40 percent gelatin in 2- by 28-inch sticks are used in the softer ground and for long-hole blasting.

In all stopes, broken ore is moved by means of hoe-type scrapers 36 to 60 inches wide. Scrapers have adjustable bails that can be set at three angles to give maximum digging effect in the ore being slushed. Scrapers are powered by double and triple drum scraper hoists rated at 15 to 25 horsepower; 250-volt direct current is used for all scraper hoists. Ore is slushed from the

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mill raises to the grizzly chute and passes directly to the shaker conveyor, the shaker discharging to the main haulage ore chute.

Virtually all stoping is done under labor contracts, three men comprising a contract crew; one man does the slushing, supervises operation of the shaker, and does any necessary miscellaneous work; the others drill and blast. Formerly, the scraper man also operated the shaker conveyor, but it was found to be better to have a full-time man in the shaker drift to control loading and shaker operations. This man is on company account.

Haulage

For main haulage on the 6th level, the equipment used is two 6-ton, 250-volt, direct-current trolley locomotives with a possible speed of 4.5 miles per hour. Trains are made up of fifteen 3-ton, round-bottom cars with an inside width of 48 inches and length of 86 inches at the top. Their depth is 36 inches.

Track is 40-pound rail set at 30-inch gage and a grade of about 0.5 percent in favor of the load. It is cross-bonded at the switches. At present the hauling distance is 2,600 feet for the round trip. The time required to complete the trip is about 25 minutes. One tramming crew of a motorman and two helpers or loaders and a skiptender handle the entire daily production of about 1,100 tons.

Cars are dumped by an air-operated rotary dump, which is controlled by a three-way valve. The ore is dumped on a grizzly (the fines going through) ahead of a Blake-type jaw crusher and, after being crushed, passes to a shaft pocket, from whence it is drawn to measuring pockets and then to the skip. Shaft pocket capacity is about 50 tons. The measuring pockets hold 3-1/2 tons or a skip load.

Shaker Conveyor

At the beginning of stoping operations on the block of ore where the shaker is now installed, it was necessary to use two shaker units to move the broken ore from the extreme limits of the ore body to the main haulage ore chute. One of the units was installed to handle the ore from that part of the ore body that extended above and off the main block and for transferring this ore to the unit now in operation, which was to handle the ore from the main block. As soon as this smaller body of ore, about 60,000 tons, was mined out the shaker was removed. To date the shaker now operating has handled the entire tonnage from the block, a total of about 160,000 tons.

As operated at present, the unit conveys between 200 and 250 tons per day for distances ranging from 260 to 90 feet and averaging about 180 feet. Figure 14 shows the general lay-out in the shaker conveyor transfer drift.

The shaker drive unit is powered by a 20-horsepower, 250-volt, direct-current motor. Motor speed is 230 r.p.m. Speed is reduced by means of reduction gears housed within the unit. The unit trough is directly above the

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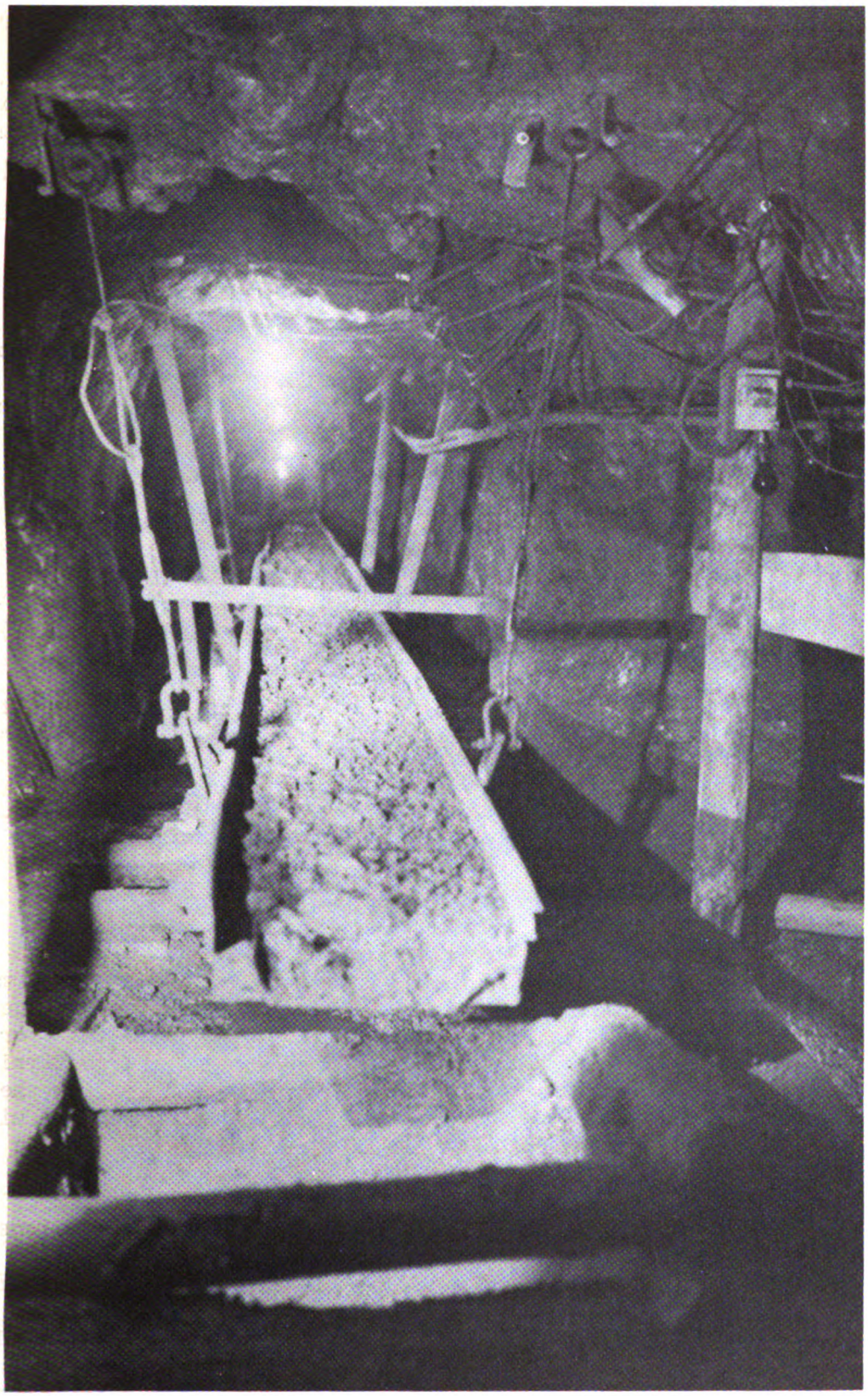

Figure 14. - Shaker conveyor transfer drift at James mine, showing trough line discharging to ore raise.

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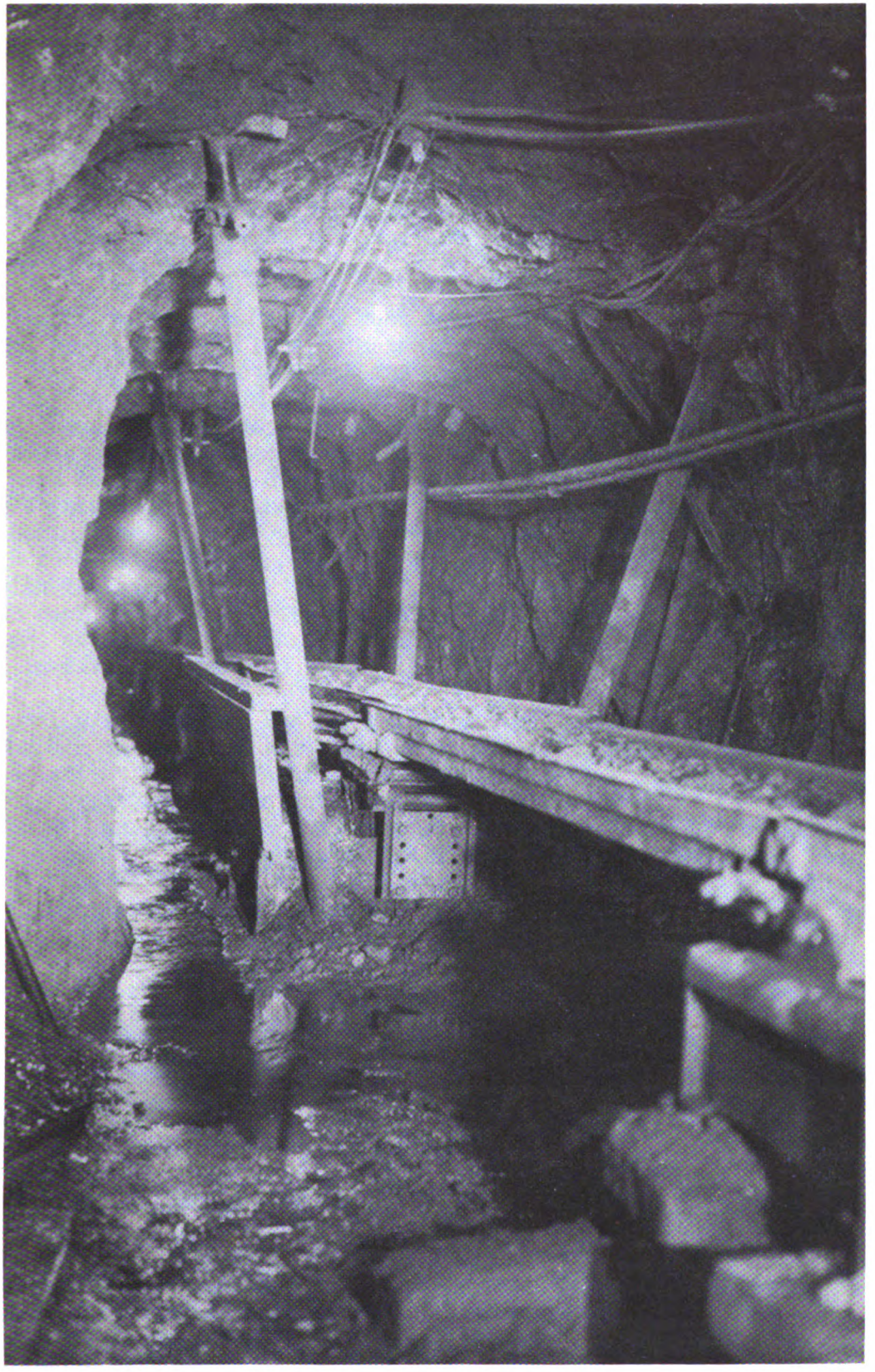

Figure 15. - Shaker conveyor drive unit at James mine, showing ratchet jacks for holding unit in place.

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drive unit and operates at 67 to 68 strokes per minute with a stroke length of 9 inches. Four ratchet jacks are used to hold the drive unit in position. A view of the drive unit is shown in figure 15.

Push-button controls are located at each loading chute and at the discharge end of the shaker. The only control that will start the shaker is the one that had just previously been employed to stop it. By this arrangement the operator must inspect the last chute drawn and see that all is clear before drawing from another.

The trough or pan line is 280 feet long. Troughs 10 feet long and having a sectional area of 115.56 square inches are used. These are lined with ordinary 1/8-inch steel plate up to the first shoulder and are reinforced by welding 2- by 2- by 1/4-inch angles to the sides of the trough in line with connecting lugs. This is done to prevent buckling. The ends of the troughs are squared accurately, and a 3- by 3/8 inch strap is welded across the bottom of the trough back from the overlapping end to permit a 1-1/2-inch overlap and to make the troughs fit squarely. Thus, motion is transmitted evenly through both connecting lugs. This, with the reinforcing angles, helps to keep the troughs in good alienment, thereby causing less strain on the lugs. Each trough, with the exception of the discharge trough, has a ball-frame type of support at each connection. The discharge end of the last trough is swung from cables, as seen in figure 14. The trough line is set on a grade of about 1 percent in favor of the load.

In loading the shaker, ore is not drawn from the chutes but is allowed to fall through the grizzly raise and chute directly onto the shaker. A board is used to deflect the ore in the direction of the flow line of the shaker. Side boards, built up to a height of about 4 feet in front of the chutes and about 8 feet along the line of the troughs, prevent spill. No levelers are used, and although a small amount of spill does occur at times, just past the side boards, the bulk of the ore in the troughs is leveled by the shaking motion. In shaking from the chutes nearest the ore raise or discharge end, the trough line is disconnected at the first joint past the chute being drawn.

Although the shakers have required considerable repairs of a minor nature, the over-all operation has been fairly satisfactory, and the management contemplates their continual use for transfer haulage. Benefits are particularly apparent where scraping distances exceed 75 or 100 feet, as the shaker will handle ore more efficiently than scrapers beyond those distances.

MINE "A"

Mine "A" is on the Menominee Range in the vicinity of Crystal Falls, Iron County, Mich.

One of the latest conveyor installations in the underground mines of the Lake Superior district has been completed only recently at Mine "A" and consists of two belt-conveyor units 275 and 325 feet in length. The units have been installed in the transfer sublevel drifts of stopes on a newly developed block of ore being worked from a 10th level. The conveyors are used for transferring broken ore from stope raises to main haulage ore raises.

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Prior to completing the installation, which to some extent was undertaken as an experiment, the management concluded that a considerable amount of development on the main haulage level and in the stopes could be eliminated by the use of belt conveyors instead of scrapers for transfer haulage. Also, it was believed that a conveyor installation would result in more efficient stoping, permitting broken ore to be moved faster and with less man power than would be required if conventional slushing methods were employed.

As the conveyor units have been installed for only a short time and actual stoping has just been started, neither of the units has as yet operated at full capacity, and no extensive operational data are available. Therefore, mining and the conveyor are described here only briefly, and the mechanical features of the conveyor are described with the understanding that the final installation may involve some changes.

Description of the Deposit

The ore deposits at Mine "A" occur in iron-bearing beds of the Iron River formation. This formation, usually infolded and interbedded with the Michigamme slate, a member of the Upper Huronian series of sedimentary rocks, is composed largely of ferruginous cherts and slates, iron carbonate, and iron ores.

In the vicinity of the mine the general trend or strike of the formations is apparently east and west. The dip is usually steep and varies slightly from vertical to steeply north or south. The strike and dip of the ore deposits as a rule follow the bedding of the iron-bearing formation.

Generally the ore deposits are bounded on both the hanging and footwall by a black, carbonaceous, and pyritiferous slate. However, along the hanging-wall, a thin bed of hard, cherty, iron-bearing rock is occasionally found in contact with the deposits and forms the hanging-wall boundary.

The ore bodies range in width from a few feet to well over 200 wherever folding has caused buckling and duplication of the beds, but generally the average width is about 100 feet.

The ore is a nonbessemer type and is composed principally of hematite and limonite. Although some of it is fairly soft, it contains many hard ribs of hematite, and as a whole is classed as a semi-hard ore. It breaks fairly fine, and only a normal amount of secondary blasting is required. It is a sticky ore and, regardless of the moisture content, whether the normal 9 percent or whether additional water has been mixed with it during slushing operations, it tends to pack tightly and hang up in the chutes. This causes considerable delay at both the chutes and the ore pockets at the stations. It is too sticky to be moved with a shaker-type conveyor.

Production

At present the mine is producing about 1,500 tons of ore per day. The total number of employees is about 185. Two shifts are worked per day, and of the crew of 90 to 95 men employed on each shift, 60 to 65 work underground.

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Hoisting

Access to the underground workings is through a vertical 4-compartment shaft 1,783 feet in depth. The shaft, 6 feet 6 inches by 22 feet 4 inches inside the sets, is divided into two skip compartments, one cage, and one manway compartment. Pipe and cable are hung in the manway. It has timber sets throughout, except for the top 38 feet, which is of reinforced concrete. Timber lagging is used.

Ore is hoisted in two steel skips operating in balance and having a capacity of 3.7 tons. Weight of the skips is 4,500 pounds. A steel cage with a capacity of 14 men and weighing about 2,800 pounds is used. Cables for both skips and cage are 1-1/8 inches in diameter.

Mining Methods

Most of the ore is mined by sublevel stoping. Development of the stopes follows the usual cycle of operations. Manways and ore raises are raised from the main haulage level to the scraper or transfer sublevel drift, the manway being carried through to the level above. The scraper sublevel drift then is driven to the limits of the ore, and from this the starting raises and mill raises are advanced and actual stoping operations begin. Because of the stickiness of the ore, scraper sublevels are usually driven on a level with or only slightly above the back of the main haulage drift in order to eliminate the necessity for chutes.

Long-hole drilling is standard practice. Holes up to 35 feet in depth are drilled from the sublevel in a radiating pattern forming a semicircle above and to the sides of the sublevel, the round breaking all ground between sublevels and for about 35 feet on each side. Most drilling in the stopes is done with drifters using 1-1/4-inch round steel with detachable bits.

Hoe-type scrapers 36 to 48 inches in width and driven by 15-, 20-, or 25-horsepower double-drum scraper hoists are used in stope transfer drifts, the ore in most of these being slushed or scraped directly into cars. Chutes are eliminated wherever possible, as the ore is sticky and tends to hang up in the chutes, causing considerable delay in scraping and tramming.

In developing the block of ore where the conveyors are now installed, a manway and one chute were raised from the 10th level at the east end of the block or the corner nearest the shaft. These were driven to a height of 35 feet above the level to where the transfer sublevel drifts were to be started. A timbered transfer sublevel 8 by 9 feet in section was then driven, roughly at right angles to the direction of the haulage level, a distance of 340 feet to the westerly limits of the block. A crosscut was also driven from the top of the ore chute in a southerly direction or parallel to the main haulage level a distance of 60 feet, to the location of the second transfer drift. The latter drift was then driven parallel to the other sublevel for a distance of 275 feet to the western limits of the ore.

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Ore chutes for loading the belts were raised from the transfer drifts to the scraper sublevel. In each of the transfer subdrifts a chute was run up near the tail end of the conveyor, or at approximately 305 and 265 feet from the ore raise leading to the main haulage level. A chute is shown in figure 16. At about 130 feet back towards the head pulley from the chutes, other chutes were raised in each transfer drift to the scraper sublevel. A view of one of the chutes is shown in figure 17.

With the completion of this work, the scrapers were removed and the conveyors were installed, ore coming from other stope development work being handled by the belts. The belt-loading chutes were installed in the center of the drift directly over the belt, being so arranged that the ore would flow to the center and in the direction of travel of the belts.

Haulage

For underground haulage on the 10th or main haulage level, three 6-ton, 250-volt, direct current trolley locomotives are used. Locomotive speed is 6.5 to 8.5 m.p.h. Trains are made up of 5 to 10 3.8-ton, box-type cars which are equipped with roller bearing wheels and are coupled for rotary dumping. The number of cars in a train depends somewhat on whether the train is hauling from outlying stopes or ore passes or is on main line haulage. Track gage is 30 inches and the grade is with the load. The haulage distance is about 5,000 feet per round trip. Only a motorman rides the train. Loading is done by loaders at the chutes, and dumping by the rotary dump operator.

No station pocket is used. Cars are dumped by means of an electrically operated rotary dump, the ore passing through one of two chutes directly to the skip. Selection of the skip to which the car is dumped is controlled by air-operated gates on each chute. As an additional precaution against dumping to the wrong chute and spillage into the shaft, signal lights are to be installed to indicate which skip is in position for loading.

Belt-Conveyor Installation

The conveyor units were installed during November 1947. The two units, identical except in length, measure 275 and 325 feet between center line of head pulleys and tail pulleys. The belts, which are made of Buna rubber with 6-ply, 32-ounce duck, are 30 inches wide. Top cover is 3/16 inch thick, and bottom cover is 1/16 inch thick. Speed of the belts is 180 feet per minute.

Each unit is driven by a 15-horsepower, 440-volt, 3-phase, 60-cycle, 1,745-r.p.m. induction motor. A drive assembly is shown in figure 18. The motor is connected through a flexible coupling to a reduction gear with a reduction ratio of 15.25 to 1. Power is transmitted to geared tandem drive pulleys by 14- and 36-tooth sprockets and a 2-inch pitch chain. The sprockets are keyed, respectively, to the shaft of the speed reducer and the tandem drive pulley. The motor and reducer are mounted on a base separate from the head or drive-end section and so arranged that it can be set up on either side of the section to drive the unit either from the right or left.

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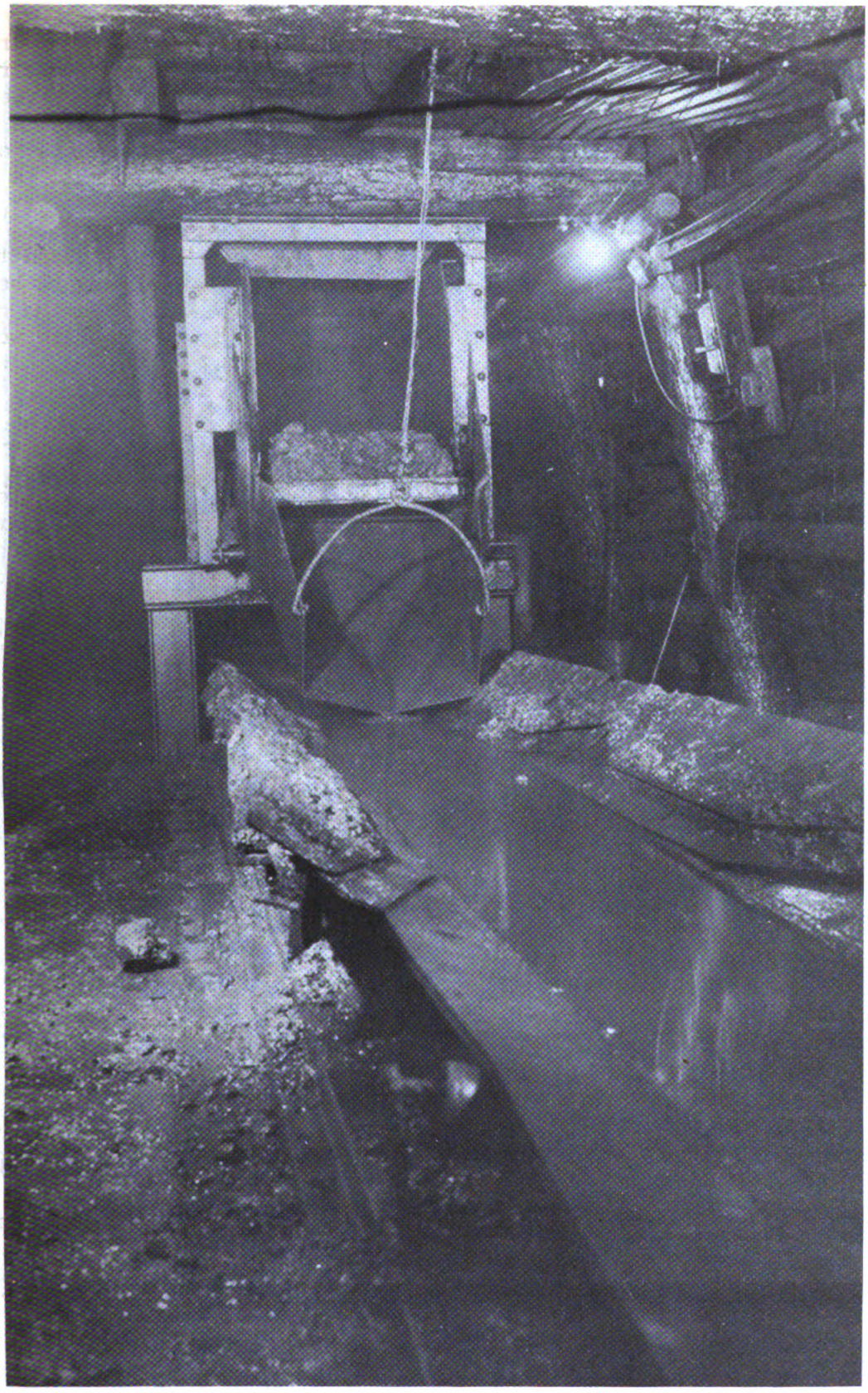

Figure 16. - Reciprocating feeder with movable chute on transfer sublevel at mine "A".

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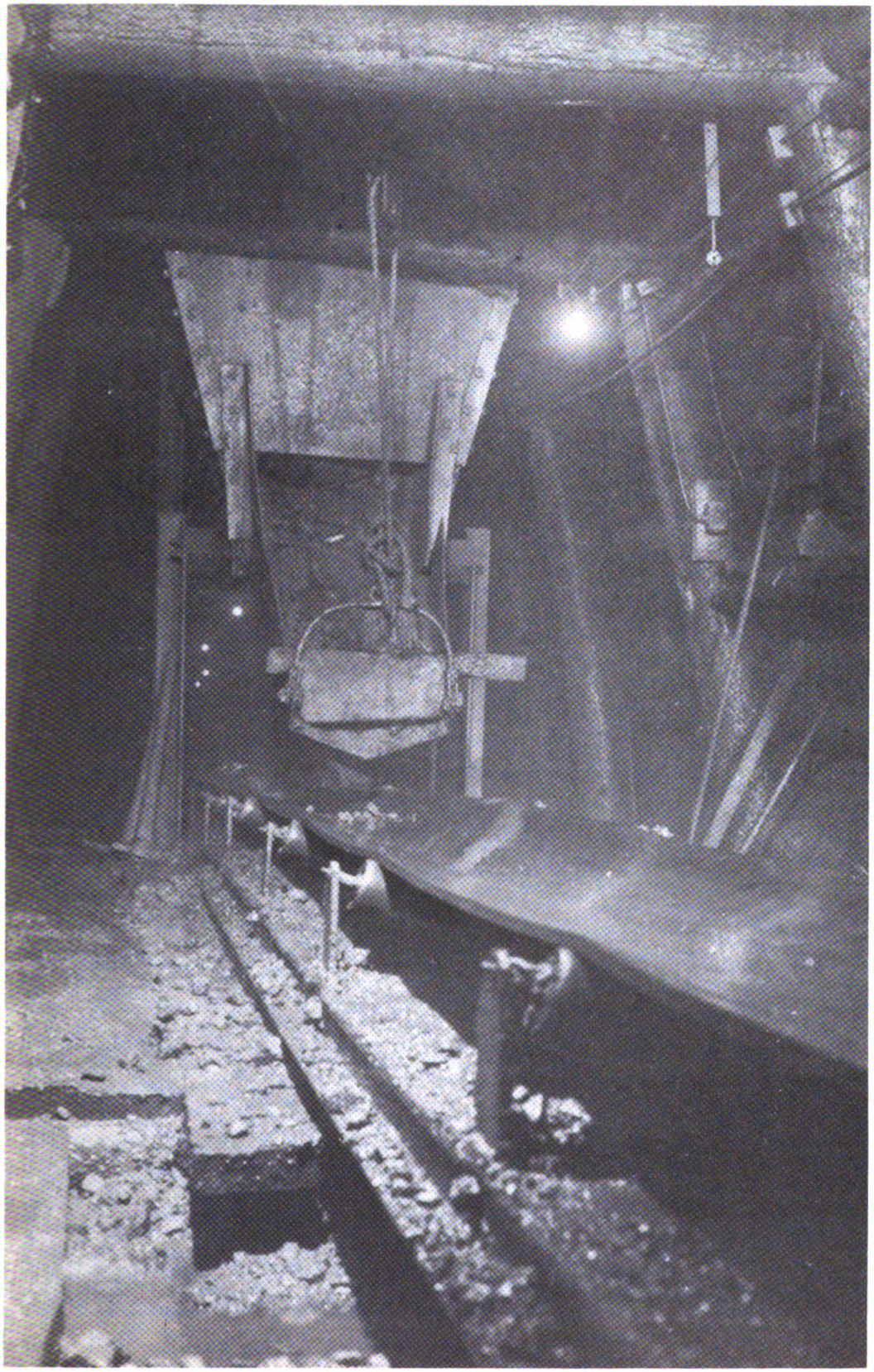

Figure 17. - Steel hopper and chute to transfer drift at mine "A".

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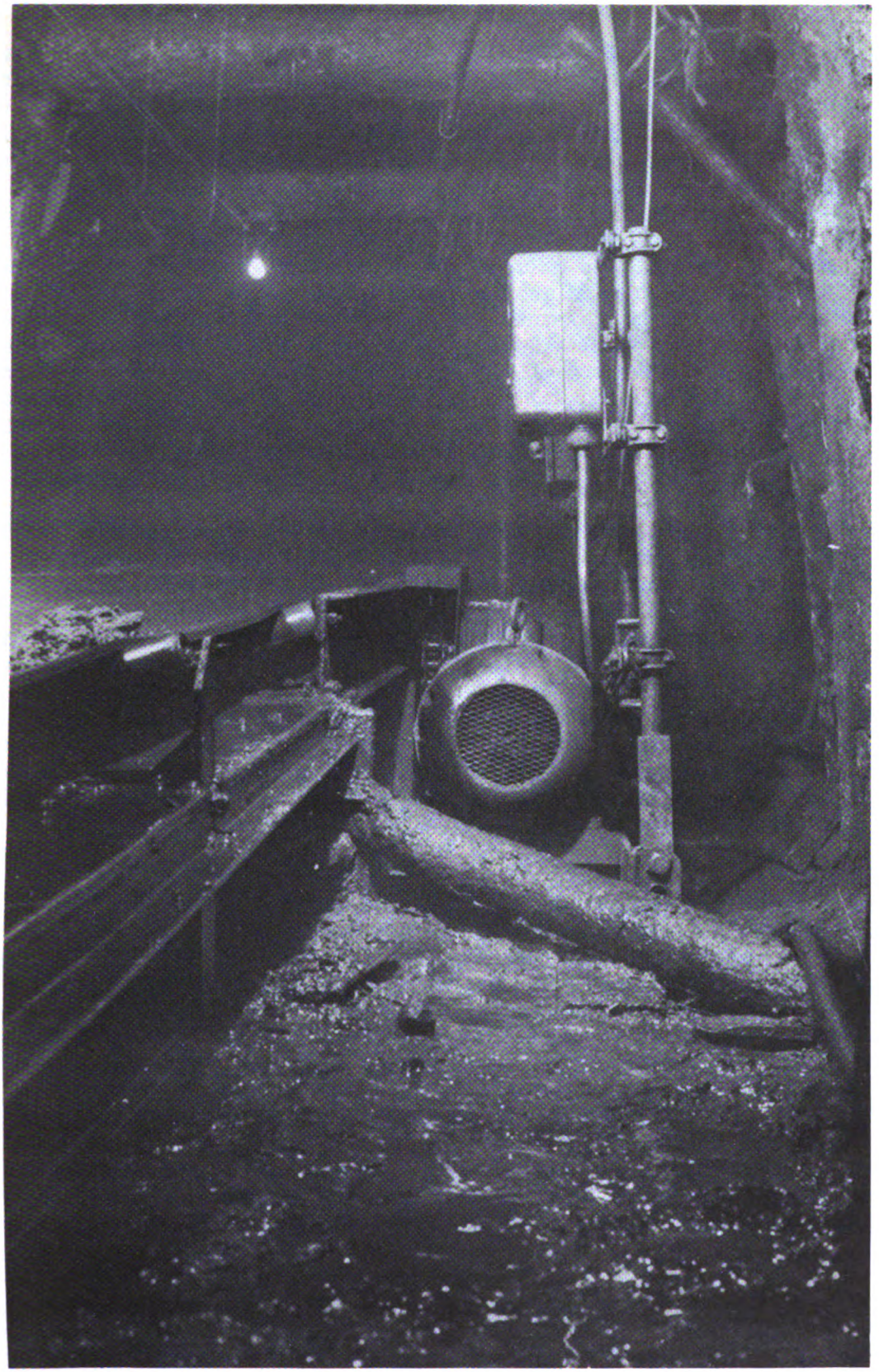

Figure 18. - Motor drive assembly and control for transfer conveyor at mine "A".

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Conveyor frames are built in separate sections. The head or drive end section comprises an overhanging head pulley and the tandem drive pulleys, which are mounted on a skid frame 16 feet 11 inches in length. Two special sections, each 8 feet in length and also mounted on skids, are used next to the drive section. Between these and a special, intermediate, tail end section, standard 8-foot intermediate sections are used. The tail end section is constructed so that it telescopes into a special 8-foot intermediate tail-end section, thereby making it adjustable for tightening or loosening the belt. Maximum and minimum lengths of the tail end section are 10 feet and 5 feet, thus permitting a 5-foot adjustment. All sections have removable cover plates for protection of the underside of the belt. Diameter of the overhanging head pulley is 16 inches and of the drive pulleys 16-3/4 inches. The tail pulley has a diameter of 12 inches. Head and drive pulleys are crowned, and the drive pulleys have a rubber facing. Tension is taken up by chain and jack. A chain attached to the tail end section frame is anchored to the ground through an eye-bolt and then jacked to the desired tension. The head end is held in position by adjustable hook and eye bolts.

Carrier rollers, three to the set, have the two outside rollers set at an angle of 20 degrees and the center roller horizontal and offset from the line of outside rollers toward the tail end of the conveyor. Diameter of the carrier rollers is 3-1/2 inches, and they are spaced at 4-foot intervals. The return rollers are 2-9/16 inches in diameter, and they are spaced on 8-foot centers.

Two 3-bladed plough-type scrapers are used for cleaning the belts. These are placed between the head pulley and the first drive pulley. Scraper blades are of rubber and are adjustable for wear. A special hold-down roller in back of the head pulley also helps to keep the belt against the blades. A single-blade plough just ahead of the tail pulley is used to clean the underside of the belts.

The standard conveyor section is made up of two angle-iron runners with a cross chair support at 4-foot intervals; all sections are bolted together for rigidity. The standard sections can be dismantled for moving or can be moved as a unit or in as many units as desired. Section frames are set to allow a clearance of 12 inches between the return belt and the ground, except at the head-pulley end, where the clearance is about 20 inches, the top belt being 36 inches above the ground. With only a 12-inch clearance, it is difficult to remove spillage and fine material that builds up under the frames, particularly when a wet and sloppy ore is being conveyed.

Push-button switches for starting and stopping are installed at the head end of the conveyors and at the chutes; also, a small cable connected with the main switch is strung along the drift, so that the conveyor can be started or stopped from any point in the drift.

To prevent overloading of the main-haulage ore chute at the head end of the conveyor, a solenoid switch activated by the ore or rocks hitting a plate throws the main switch and stops the belt. The plate is set near the top of the chute in order to permit loading to maximum capacity.

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Three types of chutes or hopper-chute combinations have been tried for loading the belts. They have been constructed of both steel and timber. The timber chute is similar in design to conventional ore chutes except that the bottom is longer, the throat has been reduced to 24 inches in width, and no stop gate is used. A hinged chute lip serves as a gate, when needed, and checks the run of ore in addition to guiding it to the center of the belt. The metal hopper shown in figure 17 has an adjustable chute lip. The movable lip can be raised or lowered and is used as a stop gate as well as to direct the flow of ore. The wooden hopper is similarly equipped.

The third belt loader installed, is a reciprocating plate feeder, which consists of a straight-sided hopper with a sloping back and a movable plate on rollers for a bottom. The unit is driven by a chain and sprocket drive, power being transmitted through a speed reducer having a reduction ratio of 17.5 to 1. The speed reducer is connected to a 10-horsepower, 1,750 r.p.m. induction motor operating on 440-volt, 3-phase, 60-cycle, alternating current. The feeder is equipped to be operated from the tail pulley of the conveyor; however, in this instance a separate drive is used. The hopper has a capacity of 3/4 yard, and, with the plate set at 67 strokes per minute, 250 tons of ore per hour, can be fed to the belt. The feeder and an adjustable chute lip constructed by the company for better control of the feed to the belt are shown in figure 16. Although the author saw the feeder and chute lip in operation for only a short time, and then when a wet and sticky ore was being handled, the feeder and chute lip combination operated satisfactorily, placing a uniform load in the center of the belt.

Owing to the short period during which the conveyor units have been installed, insufficient data have been obtained to be able to judge the effect the units may have had on stoping and tramming operations and the cost of transfer drift haulage.

It was learned later that the company had built and installed another loader similar to the plate feeder described above and had mounted it with wheels for moving on track along the conveyor. The drive mechanism consists of a 5 horsepower, 1,740-r.p.m. motor with a chain and sprocket drive and a speed reducer with a reduction ratio of 46 to 1.

The loader is pulled from chute to chute along the conveyor by small air-operated tuggers.

So far, this arrangement for loading the belt from widely spaced chutes has proved very satisfactory.

BENNETT MINE

The Bennett mine is on the Mesabi Range in Itasca County, Minn. The mine is operated by Pickands Mather & Co. The conveyor installation in the Bennett mine, first employed in 1938, is the most extensive and complete conveyor haulage system in the underground iron-ore mines of the Lake Superior region. From 1938 until late 1946, the mine was the only underground mine in the entire region that used belt conveyors for main haulage, and at present it is the only mine in which all ore is hauled entirely by conveyors.

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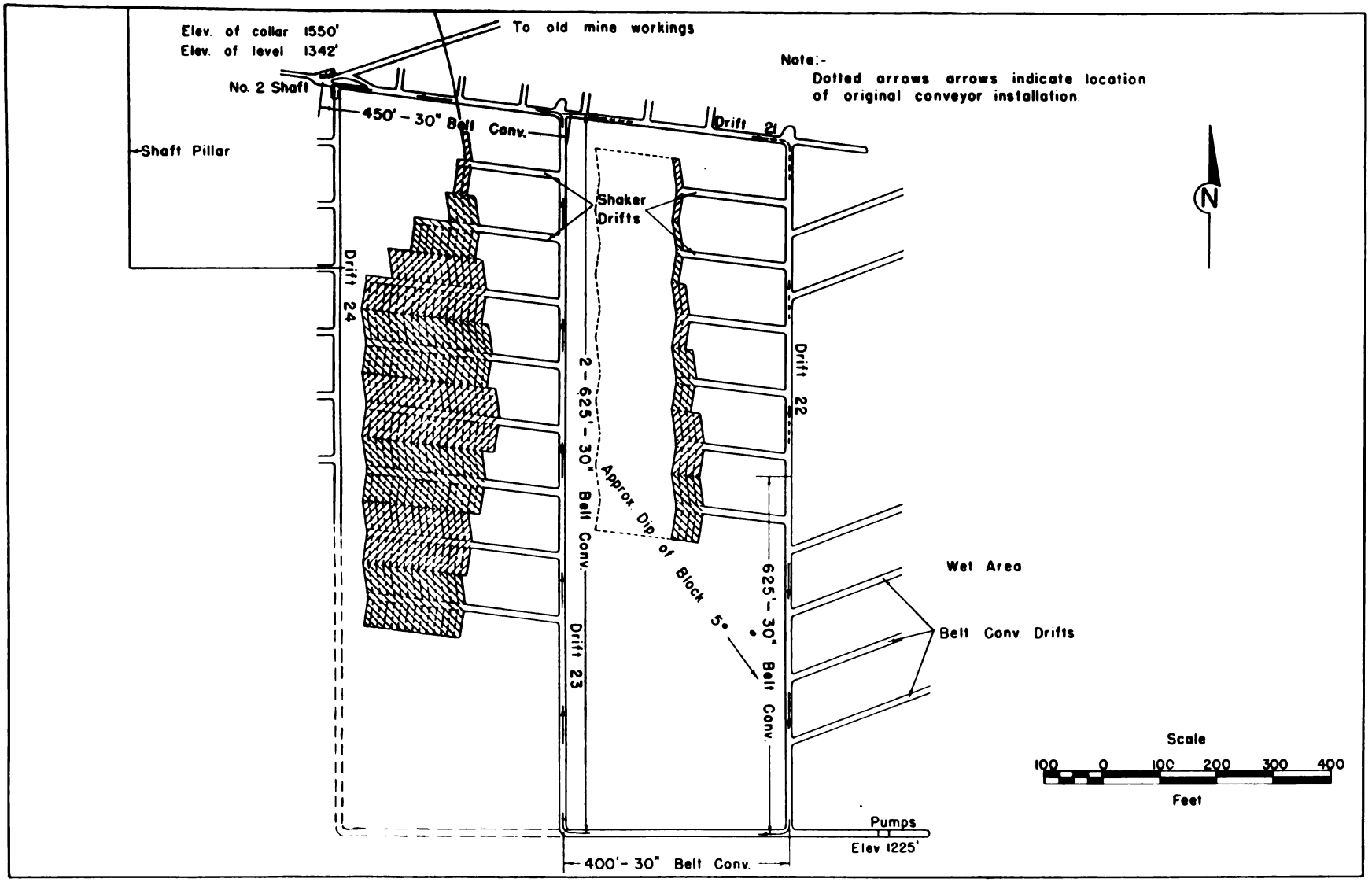

Figure 19. - Plan of mining area, Bennett mine, Itasca County, Minn.

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Before starting development of the block of ore that is now being mined, tentative consideration had been given to a plan whereby the block would be mined by a slicing method in which broken ore could be drawn directly to a main haulage level below the block. This involved considerable development, all in barren ground. The shaft would have to be sunk to a depth of 350 feet to take it below the lowest part of the ore body, and a main haulage level with ore raises would have to be driven. Moreover, the ore from the block would have to be hoisted an additional 120 feet. For various reasons the plan was carried out to the point where the shaft was sunk to the 250-foot level. Then the management decided to develop and mine the block by the present method; that is, in the plane of the ore body using scrapers and conveyor haulage.

The two principal reasons for the decisions were that all development work could be done in ore and that a substantial saving in development costs would result from the fact that no ore raises would be required. The company had previously used belt and shaker conveyors in another part of the underground operation, and from this experience knew that conveyors could be used effectively for underground haulage of iron ore.

Final plans involved installation of belt- and shaker-conveyor haulage systems and using scrapers with the conveyors for handling the ore from development headings as well as from stoping operations.

No data on the cost of operation, power consumption, or other items were available for publication, and in the following paragraphs only a general description of the mining operations and the haulage system can be given.

Description of the Deposit

The ore deposit occurs in the Biwabik formation, an iron-bearing member of the Upper Huronian series of sedimentary rocks that are found throughout the iron ranges. A series of ferruginous cherts and slates of the iron formation are associated with the deposits. Thin seams of paint rock, a soft clayey alteration product of the slates, are also associated with the deposit. These seams usually occur immediately adjacent to the deposit, often marking the limits of the ore. One such seam occurs along the footwall of this deposit. The hanging wall is a soft, sandy, cherty rock and requires timbering in even small openings. The part of the ore body in the area shown in figure 19 is tabular in shape and averages about 12 feet in thickness. Its lateral extent was not learned; however, it is known to extend about 1,250 feet south and 1,200 feet east from the shaft.

The general dip of the ore body is to the southeast, about the same as that of the iron-bearing formation, and averages about 5 degrees. Both the dip and the thickness are fairly uniform throughout the working area, although the dip occasionally exceeds the average of 5 degrees.

The ore is classed as a non-bessemer type and is composed principally of hematite and limonite. It is soft and fine-textured and breaks exceptionally fine. Its softness and texture make it easy to drill and break, and when dry

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it is an ideal ore for handling either with the scrapers or belt and shaker conveyors. An idea of its fineness can be gained from reference to the belt load shown in figure 20. The ore will average about 14 cubic feet per long ton, measured in place, and approximately 125 pounds per cubic foot when broken.

Production

The mine, with an underground crew of about 100 men, is at present producing 800 to 900 tons per day. In production areas, only the day shift is worked during a 5-1/2-day work week.

At the time the mine was visited, a major changeover to a new working area in the block was in progress, and production was somewhat below normal.

Hoisting

Entrance to the working area and hoisting is through a 4-compartment vertical shaft near the northwest corner of the block.

The shaft, originally sunk to a depth of 350 feet, is now open only to the 208-foot level. It is 11 by 14 feet inside the timbers and is divided into two skip compartments, one cage compartment, and a combined manway-pipe compartment. Timber sets and lagging are used throughout.

For hoisting, two single cylindrical-drum hoists driven by 150- and 300- horsepower, 2,200-volt, alternating-current induction motors are used, respectively, for the cage and skip. Drum dimensions for the cage and skip hoists are the same, being 7 feet in diameter with a face width of 6 feet. Both hoists wind the cables over and under. The diameter of the cable on the cage hoist is 1-1/8 inches, and on the skips it is 1-1/4 inches. Rope speed is 400 feet per minute on the cage and 1,000 feet per minute on the skips. Skips are hoisted in balance, and a counterweight is used to balance the cage.

Steel skips weighing about 3,000 pounds and having a capacity of 3-1/4 tons are used. Skips are loaded directly from a 90-ton-capacity pocket on the 208-foot level. No measuring pockets are used. The cage, also constructed of steel, weighs 3,000 pounds and has a capacity of 20 men.

Mining Methods

Only that part of the mine where the conveyor haulage system is installed is shown in figure 19. The figure, which omits much detail, outlines the mining area and illustrates, in a general way, the system of mining. It is intended primarily to show the location, lengths, and direction of main conveyor haulage and the position of the shaker conveyors in relation to the main haulage.

The uppermost point of the ore body in this block is where the 208-foot level takes off from the shaft at an altitude of 1,342 feet. The ore body dips to the low point of the block in the southeast corner, which has an altitude of 1,225 feet, 117 feet below the high point of the level.

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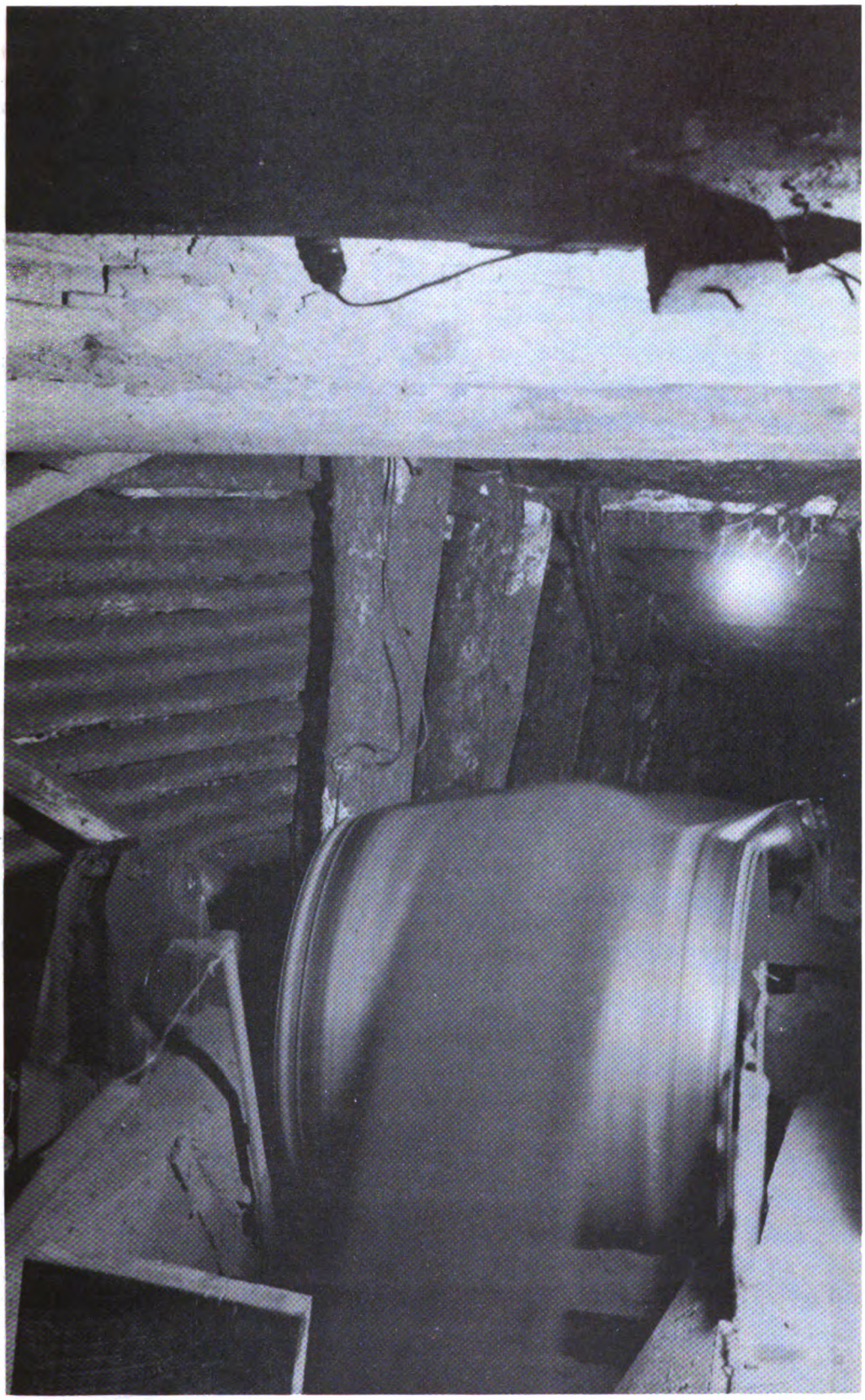

Figure 20. - Discharge end of main belt conveyor at the Bennett mine.

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Figure 21. - Timber and supply haulageway and shaker in shaker conveyor at the Bennett mine.

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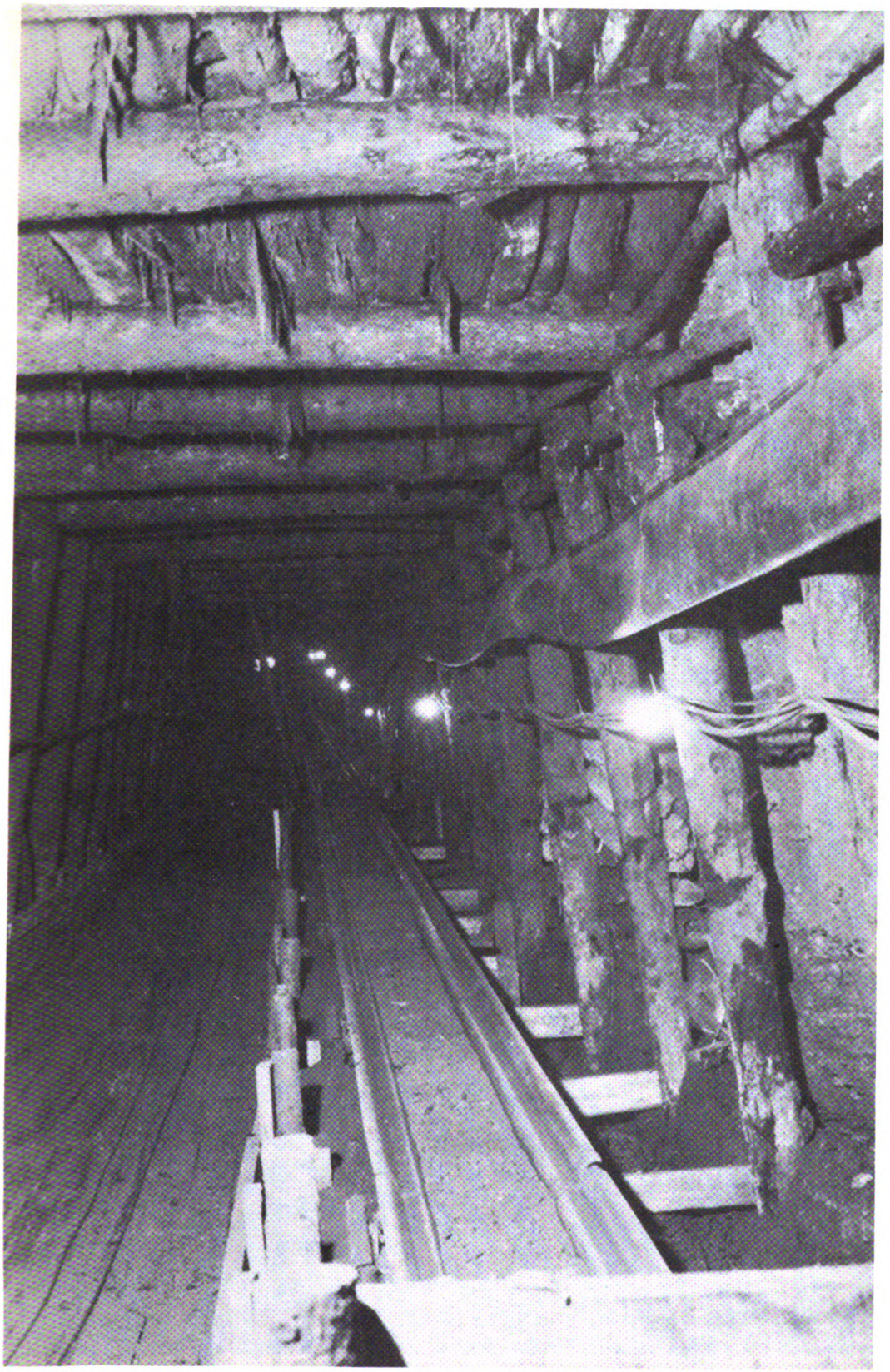

Figure 22. - Shaker conveyor drift lay-out at the Bennett mine, showing the fineness of ore ordinarily transported by shaker.

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Figure 23. - View of special grizzly for mounting over shaker conveyors at the Bennett mine.

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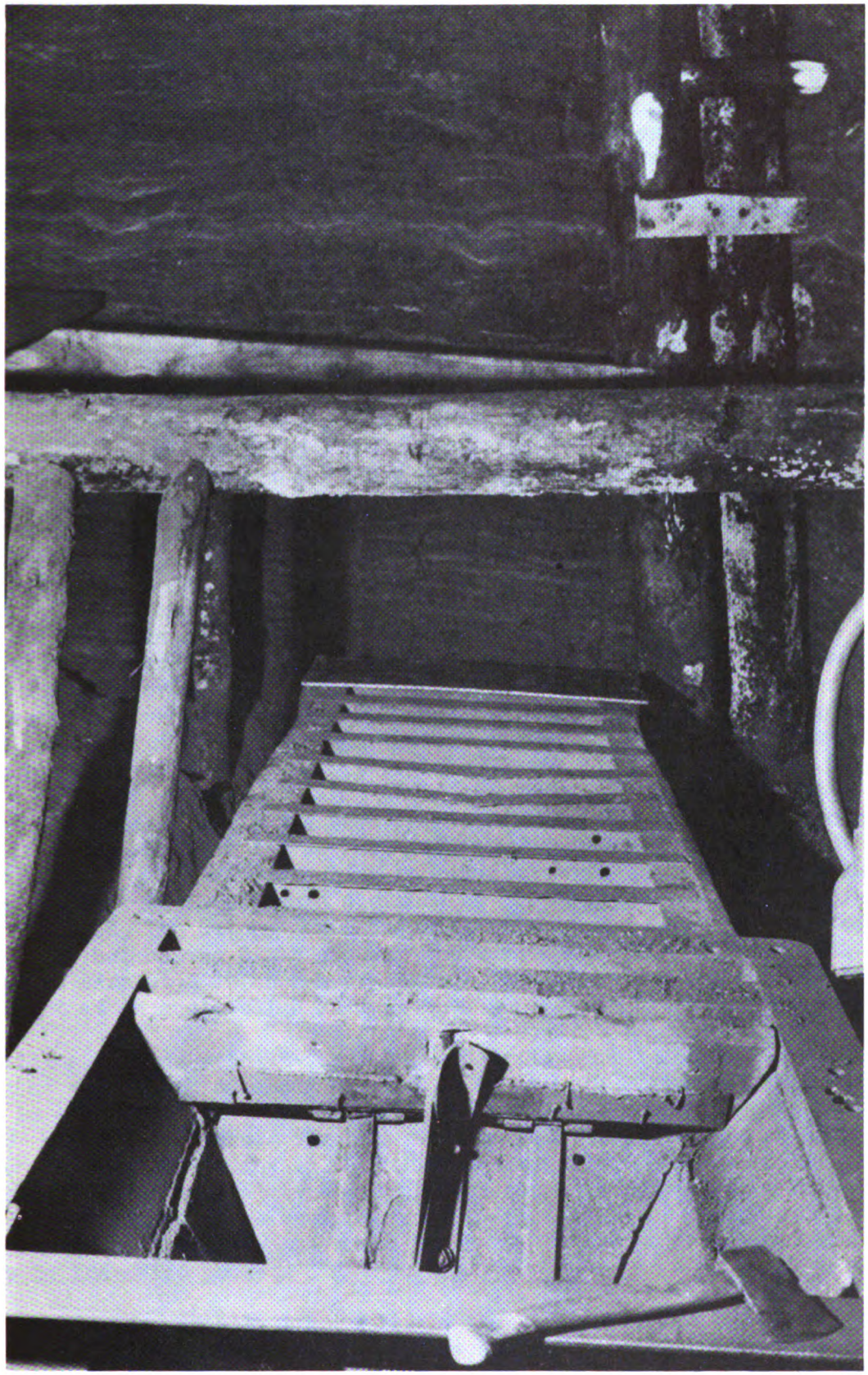

Figure 24. - Top view of shaker conveyor grizzly employed at the Bennett mine; scraper hoist base is in foreground.

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Both the dip and thickness are ideal for developing and mining the block in the plane of the ore body. The general slope of the block does not exceed the limit of incline for conveyors at any point. By using the footwall as the bottom of the drifts and stopes, the 12-foot thickness of the ore can be mined with a single slice. As all development headings were driven in ore, the conveyor drifts were made wide enough to provide ample room for the conveyors and timber slides that serve as supply and equipment haulageways. These generally follow the contour of the footwall and are wide enough to accommodate large booms of timber as well as long steel sleds, on which small supplies and equipment are hauled. Scraper hoists were used for motive power. With the arrangement for handling supplies and timber, only one loading at the top of the main drift slide is required, and no reloading is necessary in transit to the working faces. A change of cable connections from one hoist to another at the transfer point is the only move needed to get supplies to the face.

As shown on the diagramatic mine plan (fig. 19), the present block is trapezoidal in shape. The main conveyor drift, designated drift 21, bears S. 80° 40' E. from the shaft. Conveyor drifts are turned from the main drift and driven on 400-foot centers a distance of 1,250 to 1,275 feet to the No. 22 to 23 transfer drift. From the conveyor drifts, shaker or entry drifts spaced on 110-foot centers are turned to the east or west, or in some instances in both directions, at the angles shown in figure 19. They are then driven 350 feet, from which point the slices are started and operations retreated toward the main level. The working drifts are driven off normal to the main conveyor haulage drifts in order to maintain a fairly level grade for the shakers or, in the wet area, for the conveyors. The angle is also maintained to prevent running over the bottom of the ore body and leaving ore on the footwall. Views of shaker conveyor drifts are shown in figures 21 and 22.

After the shaker drift has been completed, the slice is started to each side. The slices are carried 10 feet wide through the full thickness of the ore. In advancing the slices, which go simultaneously in both directions from the working drift to an ultimate distance of 50 feet, the ore is broken at the face and slushed, the cut on one side being made in the first one-half of the shift and the cut on the other side in the second one-half of the shift. Thus, two cuts are completed in an 8-hour shift. The slices are turned from the shaker drift at an angle slightly less than 90 degrees to facilitate scraping.

Drilling is done with 35- and 42-pound drills and 2-inch auger bits. Holes are drilled to a depth of about 6 feet, 15 to 18 holes being required to break the ore in each round properly. The rounds are blasted with 60-percent gelatin in 1-1/8- by 8-inch sticks. Slushing is done with 48-, 54-, and 60-inch wide box-type scrapers powered by 15, 25, and 30-horsepower scraper hoists. Broken ore is scraped to a special type of grizzly, shown in figures 23 and 24. This has a 6-inch opening and is equipped with a special shaker trough for connecting to the shaker trough line. Ore moves by shaker to the belt conveyor and then directly to the shaft pocket.

All drifts are heavily timbered. In the slices, timber is carried one set back, or within 6 feet of the slice faces. After the slice drifts have been driven the full length in both directions from the shaker drift, the

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timber sets are lined with a wire fencing, and the posts on the side away from the ore are drilled and blasted, permitting the ground to cave up to the ore in the next slice.

Most of the stoping or slicing at present is carried on in the southern half and in the southeast corner, marked "wet area" on the plan of the block (fig. 19). In this area, four conveyor drifts have been driven, and 400-foot belt conveyors are being installed preparatory to slicing. This is the only part of the block in which water has been encountered; and as the shakers will not handle a wet ore, belt conveyors will be used. These conveyors were not operated at the time of the author's visit.

Haulage

Supplies and timber are hauled the short distance from the shaft to the timber slides or runways with a 3-1/2 ton trolley locomotive that operates on 250-volt direct current. Track gage is 24 inches, and 30-pound rails are used. This is the only place in the block where hauling is done by locomotive. After being delivered to the top of the runways, the supplies are transferred to steel boats and are then dragged by motor-driven scraper hoists to the transfer points, and from thence by other scraper hoists to the working faces. For supply and timber haulage, 15-horsepower, double-drum scraper hoists equipped with 5/8- and 1/2-inch cables are used.

Belt and Shaker Conveyors

At present, 10 belt conveyor units totaling 3,925 feet in length and 6 shaker units with approximately 1,200 feet of trough are used in the ore-haulage system. The location, width, and lengths of nine of the units are shown on figure 19. A view of the main belt with the drive unit for the conveyor from No. 23 drift is seen in figure 25. The 10th unit, not shown in figure 19, is a short cross belt that carries the discharge from the main belt to the shaft pocket. It is set at right angles to the pocket.

The angle of incline of the various units was not learned; however, three of the units, one in the main haulageway to the shaft and two in No. 23 drift, appear to be inclined at approximately 10 degrees against the load. The unit in the transfer drift from No. 22 to 23 drift at the south end of the block is level except for the last few feet, where it is inclined upward at about 10 degrees so as to discharge onto the belt in No. 23 drift. At present, the single unit in No. 22 drift is being operated in reverse and runs downgrade to discharge to the No. 22 to 23 transfer unit. The belts in the wet area are level, for the most part or have only a slight inclination upward toward No. 22 drift. The maximum allowable angle of inclination is 18 degrees; however, none of the belts are this steep, except for short distances near the head pulleys.

Of the ten belts in use, eight have a width of 30 inches, and are 3/8- to 7/16-inch in thickness. The other two are 24 inches in width and 7/16- and 5/8-inch in thickness. The 5/8-inch belt has a top cover of 3/16-inch and a 1/16-inch bottom cover. Speed of the main belts and of two of the feeder or

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Figure 25. - View along main belt conveyor and drive unit for conveyor from No. 23 drift at the Bennett mine.

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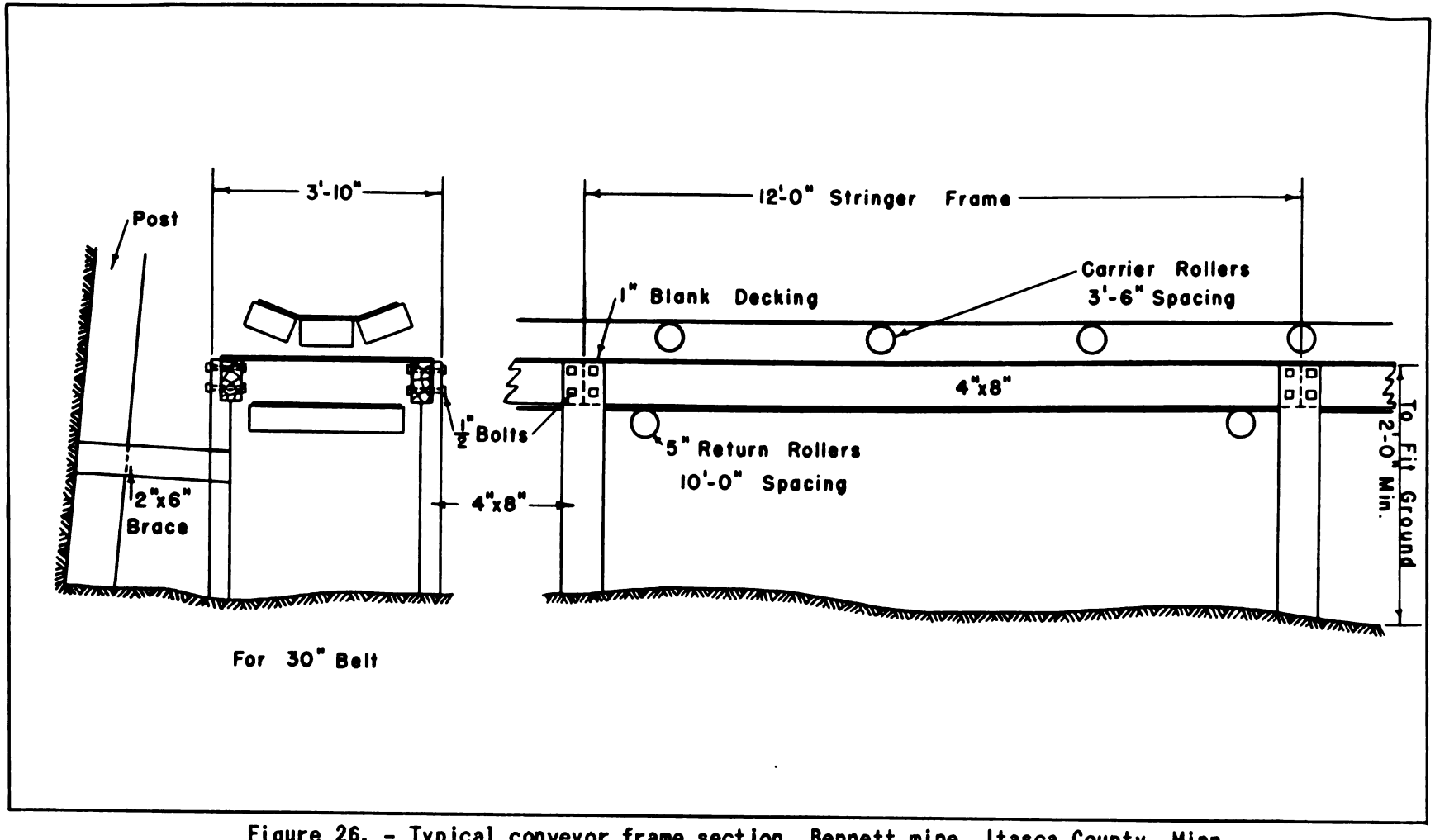

Figure 26. - Typical conveyor frame section, Bennett mine, Itasca County, Minn.

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auxiliary belts is 400 feet per minute. The other two are operated at speeds of 200 and 300 feet per minute.

On most of the units, power is transmitted to the head pulleys by means of roller chain and sprocket drive operated through speed reducers coupled to the motors. The others are driven by sprocket and chain drive direct from the motor to the head pulley, the belt speed being determined by the sprocket sizes.

Alternating current at 440-volts, 3-phase, 60-cycle is used for all motors. Table 2 gives the horsepower rating of the motors and the conveyor units with which they are used.

A screw-type take-up at the tail pulley is used for adjusting belt tension on all units.

TABLE 2. - Power requirements at conveyors, Bennett mine

Conveyor location	Belt			Motor	
	No.	Length, feet	Width, inches	No.	H.P.
Main drift	1	450	30	1	50
No. 23 drift	1	625	30	2	50
No. 22 to 23 transfer drifts	1	400	30	1	35
No. 22 drift	1	625	30	1	50
Wet area	1	400	24	1	20
Wet area	1	400	30	1	20
Wet area	1	400	30	1	10
Wet area	1	400	24	1	7-1/2
Shaft	1	25	30	1	7-1/2

On the inclined belts, a friction-type ratchet backstop or safety lock prevents the belt from running backwards after it is stopped. The back stop consists of an ordinary positive action pawl and ratchet attached to the head pulley shaft; the pawl riding the ratchet and dropping into place whenever the belt is not in operation.

Frames for all belt-conveyor units are of timber and are constructed at the mine. Each frame section is 12 feet in length, and for a 30-inch belt the width is 42 inches outside of runners. A 38-inch width is used for the 24-inch belt. The frames, as shown in figure 26, consist of two 4- by 8-inch runners and 4- by 8-inch posts for support. The posts are dapped 2 inches to form a shoulder on which the runners rest and are bolted to the runners. Both runners and posts are braced to drift sets, and where the posts are 3 feet or more in height they are also angle-braced. For the proper underneath clearance, the top of the frame is set at a minimum of 2 feet above the floor. This permits working room for replacing return rollers or for other work that may be required. Decking for protection of the under belt is of 1-inch planking.

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Various makes of carrier and return rollers are used, and these are spaced on 3-1/2- and 10-foot centers, respectively. Rollers are attached to the runners with lag screws. Five-inch-diameter rollers are used for both 24- and 30-inch belts. The carrier rollers are the troughing type, with the two outside rollers set at an angle of 20 degrees. Return rollers are 27 inches in length for the 24-inch belts, or 33 inches in length for 30-inch belts.

The system used for starting and stopping the conveyor units necessarily is designed for over-all control by means of a master switch as well as for individual control for each unit. Through the master switch, located near the discharge end of the main belt, power to all conveyors, both belt and shaker, is cut on or off whenever the main belt is started or stopped. With the main belt shut down, none of the units can be started. When the main belt is in operation, any of the units can be started or stopped as required by means of strategically located, individual, push-button controls.

For transferring ore from belt to belt where the junction is at right angles, or nearly so, an ordinary chute or slide with the bottom as steep as conditions permit is built up under and around the head pulley. This permits the discharge to fall or slide to the belt below with a minimum of spillage. In addition, skirt plates made of rubber belting and extending along the belt for 6 to 8 feet prevent spill and confine the ore until it has come to rest.

A view of the tandem belts in No. 23 drift looking toward the head pulley or discharge end of the belt coming up-grade, is shown in figure 27. The head pulley is directly under the light in the background. No chute is used, and the ore falls free to the belt. However, side boards sloped to meet the rubber skirt plates prevent spill and direct the ore to the receiving belt.

Shaker conveyors have been an integral part of the haulage system since it was installed in 1938. Here, as in the other mines described in this paper, the shakers are used in conjunction with scrapers for transferring the broken ore from the working faces to the main haulage system. They are particularly suited to the slicing method used, in that usually they have to be moved only short distances (110 feet) or from one shaker drift to the next, and they do not have to be hauled up or lowered through raises. Moreover, no chutes are required, as the ore is scraped directly from the face to the shaker. In this retreating mining method, the number of shaker troughs required is kept at a minimum, inasmuch as the troughs are available for re-installation after each slice is completed. After all slices have been taken, the shaker unit is virtually dismantled, only the drive unit and a few troughs remaining to be moved to the next shaker drift.

At present, six shaker units are being used and two others are soon to be put into operation. The 8 units, are equipped with the drive unit underneath the connecting or drive-unit trough. Each is equipped with 30 horsepower line start induction motors using 3-phase, 60-cycle, alternating current at 440 volts and is set to operate at about 80 strokes per minute, with a stroke length of 9 inches.

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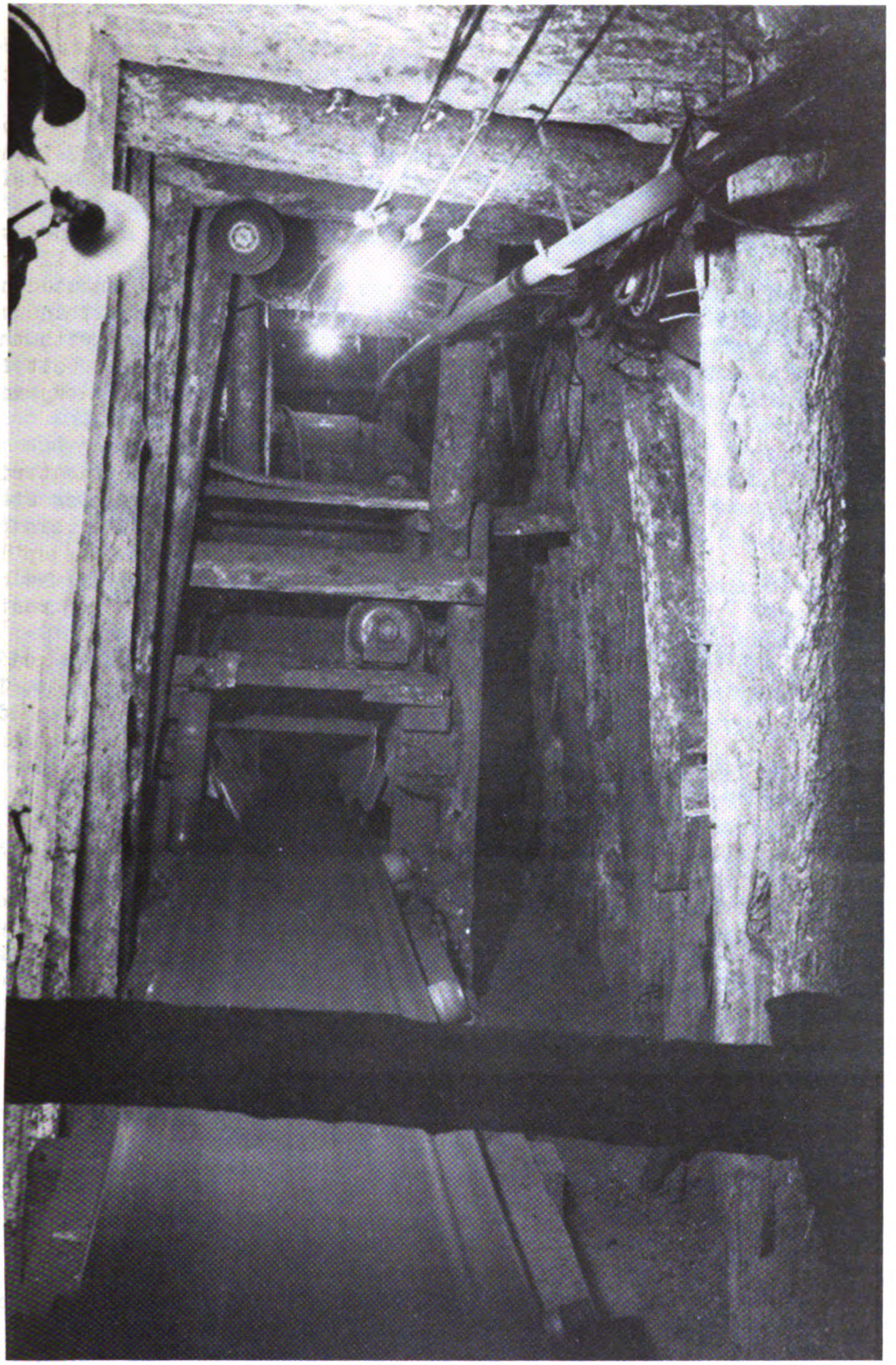

Figure 27. - Tandem belt conveyors in No. 23 drift at the Bennett mine.

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Troughs are 10 feet in length and have a cross sectional area of 115.56 square inches. They are supported at each connection and ride on a ball-race type support. Typical shaker set ups are shown on figures 21 and 22. A special trough is housed in the company-built grizzly and scraper hoist base shown in figures 23 and 24. This trough operates under the grizzly and is supported on two sets of roller-bearing wheels running in a track built into the grizzly frame. The connecting lug and a small part of the wheel and trough can just be seen in through the angle iron bracing on figure 23.

The trough bottom and sides up to the first shoulder are lined with 1/8-inch plates shaped to fit the trough. They are spot-welded to the trough but can be removed and replaced without removing the trough from the line. The liners, besides preventing wear to the body of the troughs, give additional stiffness to the entire trough line. At each connection the troughs are supported and ride on a heavy-duty ball-frame support. The support consists of a lower and top frame with housed ball races on each side of the frame unit. The upper part of the frame is attached to the trough by special lug bolts and rides and moves on the balls, which ride the housing of the stationary lower frame, this being anchored to the timber supports.

A leveler for spreading or flattening the ore to any desired thickness in the trough is located at the discharge end of the grizzly. This consists of a 1/2-inch plate hinged to the frame and set at the proper angle with the trough to level the ore as it moves from the grizzly. A bolt and spring hold the bottom of the plate in position and at the proper tension to retard the ore until it is leveled and will not spill from the trough.

An effort is made to keep the length of trough lines under 200 feet. Over this length, the operating efficiency of the shaker is cut down, and the amount of repairs increases. Usually, if a longer trough line is to be required for any length of time, a second unit is placed in the line and the units are operated in tandem. Considerable care is used in properly alining the shaker both for line and grade. The grade is not permitted to exceed 3-1/2 percent and in most instances is held to about 2 percent. Troughs are lined up as straight as possible to prevent possible buckling and to decrease the strain and wear on the unit reduction gears. The trough line discharges directly onto the belt conveyor, nothing other than short skirt boards or plates along the belt being used to center and retain the ore until it is at rest on the belt.

The push-button controls for starting and stopping the shakers are tied into the main haulage controls, and the shaker can be started only when the belt conveyors are in operation.

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